



First Record of Edible Moth *Antheraea assama* and its Nutritional Composition

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ABSTRACT

Entomophagy is an old tradition in the world, lots of edible insect species were recorded, however no any moth stage were reported as edible till date. *Antheraea assamensis* Helfer (Lepidoptera: Saturniidae), endemic to Assam and adjoining areas of North-Eastern, India is renowned principally for its silk yarn as well as for the nutritious pupae. In addition with the pupae the adult stage (moths) of *A. assama* are also taken as a delicious food item (after egg laying) by the ethnic people of Dhemaji according to their availability. Hence, the present work has been undertaken to evaluate the nutritional composition of *A. assama* moths. The female moths were procured from the muga rearers of Dhemaji and the macronutrient compositions were analyzed using Association of Official Analytical Chemists guidelines (AOAC, 1990). It was recorded that the moths contained appreciable levels of Crude protein (67.55%), Crude fat (14.44%), Crude fiber (9.73%), carbohydrate (8.04%) ash (4.8%), moisture (18.89%) and gross energy (414.56 kcal/gm). Hence, the muga moths may be an ideal alternative food source.

Keywords: *Antheraea assama*, adult stage, nutritional composition, alternate food source

INTRODUCTION

Sericigenous insects are the silk producing insects. In the midst of the five different commercial silkworm breeds, mulberry silkworm (*Bombyx mori*), tassar silkworm (*Antheraea mylitta* and *Antheraea pernyi*), muga silkworm (*Antheraea assama*) and eri silkworm (*Samia ricini*), muga silkworm is widely reared regularly for its highly demanded



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silk. Together with the silk as a byproduct of mugaculture the edible delicious pupae and the adults are obtained. The Saturniidae family have 1200 to 1500 species around the world and in India about 40 species of silk moth are reported [1,2]. Muga silkworm, *Antheraea assamensis* Helfer is widely distributed in the Brahmaputra valley, North Cachar Hills and Karbi anglong District of Assam [3], as well as in other North Eastern states like Arunachal Pradesh (Lohit District, Dibang Valley, Changlang and Papumpare Districts), Manipur (Tamenglong District), Meghalaya (East and West Garo Hills), Nagaland (Kohima, Wokha, Mokochung Districts) and South Tripura [3]. *Antheraea assama* is very precious due to its lustrous and costliest golden colored silk thread. This sericigenous insect completes its life cycle in 5 larval stages. The pupae of *Antheraea assama* were recorded as the rich source of nutrition [4]. Along with the delicious pupae the adults, are also taken as luscious food item by the ethnic people of Dhemaji. Since they are semi domesticated starting from the seed up to hatching completed in indoor and subsequently the newly hatched larvae are shifted onto the outdoor host plants. Throughout the process of rearing (including both the indoor and outdoor) lots of traditional knowledges are applied and usually in the initial stage after emerging the moths, the rearers tied up the female moth on a stick made up of thatch grass and allowed to mate with male moths[5]. Hence, after mating and egg laying the females remains in tied up condition, and are taken as delicious dishes after frying or roasting. However the consumption of edible insects depends on a variety of factors like their taste, palatability, availability, nutritional value and traditional belief system of the people [6]. Lots of research has been done on the nutritional contents of muga pupae but still there is no any report available on the nutritional contents of muga moth *Antheraea assama* [7, 8]. However data has been obtained on the adult stage of different edible insect but no any silkworm has been reported as edible till date. Hence, the present work has been undertaken and the proximate contents of edible muga silkworm moth were assessed, which may be a good supplement of nutrition.

MATERIALS AND METHOD

To record the uses of adult stage of muga silkworm as edible item extensive field surveys in five villages of Dhemaji district of Assam were conducted. The villages were Napam gaon, Deogharia, Gohaingaon, Luguti and Nahoroni. We have randomly selected the households and interviewed one individual per house. The surveys were carried out during May 2016-2019. The villagers were informed the objectives of this survey that only for academic purpose this information's were collected and then they convinced. We have interviewed a total of 100 respondents (30 female and 70 males). They were interviewed through a semi structured questionnaire includes the availability of the muga adult, mode of consumption, nutritional value and therapeutic value etc.

Sample preparation

After collection of the samples from the field they were brought to the laboratory and the wings were cut off and washed thoroughly with filtered water, blotted dry and oven dried ground to powder and stored in air tight container in deep freeze -20°C under vacuum for proximate component analysis. All the solvents and chemicals used in the study were of analytical grade and care was taken that the glassware were meticulously clean.

Estimations**Proximate estimation**

Methods and techniques adopted for the analysis are recommended by the AOAC (Association of Official Analytical Chemists, 1990). The parameters determined were Moisture, crude Protein, crude Lipid, crude Fiber, Ash and Carbohydrate.

A: Moisture

Sample was weighed oven dried at 40°C to 50°C and cooled in desiccators. The process of heating and cooling is repeated till a constant weight is achieved. Moisture content was calculated using the following formula:

$$\% \text{ of Moisture} = [\text{Initial weight} - \text{Final weight}] \times 100 / \text{weight of the sample}$$

B: Crude Protein: Crude protein content of the samples was estimated by Micro Kjeldhal method. The nitrogen content determined was multiplied by a factor of 6.25 to obtain the amount of crude protein. Nitrogen content was





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calculated using following formula :

$$\% \text{ of Nitrogen} = [14.01 \times (S - B) \times 0.1 \times 100] / [W \times 1000]$$

Where, S= 0.1N HCl required for titration of sample (ml)

B= 0.1N HCl required for titration of blank (ml)

W= weight of sample (g)

C: Crude Lipid: The lipid from the samples was extracted by solvent extraction in petroleum ether (boiling point 60°C to 80°C) using Soxhlet apparatus (Rivotek, Riviera Glass Pvt. Ltd., India). Percentage of crude lipid was calculated using following formula:

$$\% \text{ of Crude lipid} = [(W_1 - W_2) / W] \times 100 \text{ Where,}$$

W₁= weight of flask along with lipid extracted (g)

W₂= weight of empty flask (g)

W= weight of sample (g)

D: Ash: For ash estimation the sample was weighed in a crucible, followed by heating in a muffle furnace for about at a temperature 600°C and cooled and weighed. Ash was determined by using the following formula:

$$\% \text{ of Ash} = \text{Weight of the ash} \times 100 / \text{Weight of the sample.}$$

E: Crude Fiber: Defatted sample was digested with 0.255N Sulfuric acid (H₂SO₄) and 0.313 N Sodium hydroxide (NaOH), followed by drying overnight in hot air oven (80°C to 100°C) and ashing in muffle furnace (600°C). Percentage of crude fiber was calculated using following formula:

$$\% \text{ of Crude fiber} = [W_e - W_a] \times 100 / W$$

Where, W_e= weight of dried sample after overnight drying (g)

W_a= weight of ash (g)

W= weight of sample

F: Total Soluble Carbohydrates

The nitrogen free extract (NFE) or soluble carbohydrate % was calculated by subtracting moisture, ash, fat, protein and fiber percent of sample from 100 using following formula:

$$\% \text{ of NFE} = 100 - [\text{ash}\% + \text{ether extract or crude fat}\% + \text{crude protein}\% + \text{crude Fiber}\%]$$

RESULTS

Our study revealed that they contained appreciable levels of crude protein (67.55%), crude fat (14.44%), crude fiber (9.73%), carbohydrate or NFE (8.04%) ash (4.8%), moisture (18.89%), and gross energy (414.56 kcal/gm) respectively.

DISCUSSION

Since this adult stage is consumed and there is no data available on the edibility of moth stage therefore, it is quite necessary to analyze the nutritional contents of adult *Antheraea assama*. Zhou and Han reported the proximate content of muga pupae *Antheraea pernyi* as moisture 7.6%, crude protein 71.9%, crude fat 20.1% and ash 4.0% on dry matter basis [9]. The nutritional analysis of Muga pupae *Antheraea assamensis* (non deoiled) recorded to contain 7.8% moisture, 61.63% protein, 17% fat, 3.3% fiber and 4.56% ash [10] which is comparable with the proximate contents of the adult muga. As the North East India especially Assam is rich in natural resources and muga silkworm is one of such bio resources. Due to the suitable environmental condition it is widely available and cultured in Assam. Mugaculture is an essential part of assamese culture and tradition and muga cloths are traditional costumes of Assamese people. They reared the silkworm, spin the muga silk yarn and weave the cloths by themselves. Hence, it is a very noble idea of taking the waste products as delicious item. Along with the pupae the adults may also provide nutrition to the human being and as well as for other living being. It has been recorded from our study that the moths





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contain good quantity of protein, fat, fiber, ash and NFE. The analysis for micronutrient content is a need for the future and it will definitely show many more new findings. However, it may also contain some harmful components and hence further research is needed. Although the insects are consumed at various developmental stages including the eggs, larvae, pupae and adults [11] however the *Lepidopteran muga* adults are still not recorded for its edibility.

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Table.1: Demography of respondents of the study area (n=100):

	Bakal	Deogharia	Gohaingaon	Luguti	Nahoroni
Gender					
M	13	12	14	16	15
F	5	6	7	6	6
Age group					
31-40	3	4	2	4	4
41-50	6	6	5	7	6
51-60	8	7	6	6	8
Above 60Y	3	2	5	6	2



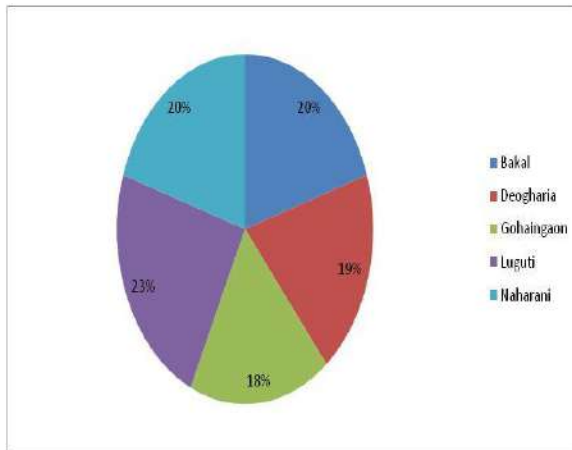


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Table.2: Macronutrients compositions of Adult stage of muga silkworm:

Stages	Moisture	Crude protein	Crude fat	Crude fiber	Ash	NFE	Gross energy
Adult	18.89±7.67	67.55±4.05	14.44±2.89	9.73±1.68	4.8±1.9	8.04±1.03	414.56

Data are mentioned as mean ± SEM.

**Figure.1: Respondents' percentage in five different villages of Dhemaji District.****Figure.2: Photo plates of A. muga silkworm, B. Cocoon of muga silkworm, C. Pupae of muga silkworm, D. Muga moths (females tied up in the kharika), E. Moths after cut off their wings and ready to process.**



A Systematic Survey of Molluscan fauna in an around Nagapattinam Coastal Area in Nagapattinam District, Tamil Nadu, Southern India

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ABSTRACT

The present study were investigated the systematic survey of Molluscan fauna in an around Coastal Area, Southern India between November 2023 to February 2024. Totally 33 Species of Molluscan Species were identified. Among the various faunal groups recorded from the Coastal area viz., Velankanni, Nagapattinam, Akkaripettai and Nagore, recorded from marine regions of India. A total of 33 species of molluscs were collected and identified. 25 species were gastropods while 8 were bivalves. Among them 25 Gastropoda and 8 Bivalvia were recorded. Totally 25 Gastropoda Species were collected during the study viz., (*Turritellacommunis*, *Canariummutabile*, *Tibia fusus*, *Murex pecten*, *Fusinus forceps*, *Rapanavenosa*, *Turbo mamaratus*, *Cypreatigris*, *Busycotopuscanaliculatus*, *Harphaarticularis*, *Semicassisbisulcata*, *Turvinellaalgalada*, *Laambis truncate*, *Xancuspyrum*, *Babylonia spirata*, *Ficusficus*, *Conus gradates*, *Chicoreusvirgineus*, *Babylonia japonica*, *Clavusbilinealus*, *Tonnadoliun*, *Phaliumglacum*, *Galeodearugose*, *Architectonicaperspectiva*, *Neveritajosephinia*) and 8 Bivalvia were recorded viz., (*Pectenmaximus*, *Anomia simplex*, *Cerastodermaedule*, *Tagelussubters*, *Pectenjacobaueus*, *Donexovariabile*, *Poradapestextilis*, *Argopectengibbus*). The distributions of molluscan fauna were influenced by various parameters such as salinity, temperature and water depth. Collected specimens were preserved in 90% formalin. The shells thus processed have been identified with the available guides,

Keywords: Molluscan fauna, Gastropoda, Bivalvia.

INTRODUCTION

Molluscs are among the most abundant of all animal. Among Marine taxa, Molluscs have achieved notable evolutionary divergence over the Phanerozoic and acquired a unique variety of morphologies (Scpkoski 1981[1],



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Russell Hunter 1983)[2]. In Particular; the evolution of a hard outer skeleton (Shell) has been associated with a great divergence of morphologies in group. White shell is useful of as an effective to the internal tissue(Stanley 1970,[3] 1988, Vermeij 1977[4], Raffalli 1982[5], Kardon 1988[6]).The whole body is covered by a single layer of epithelium, which, in parts not protected by the shell. The ventral side of the body in the Mollusca is characterised by the pronounced Development. The foot may become much modified in adaptation to various methods of life and of locomotion, in fact, it may entirely lose all resemblance to the primitive organ. The Molluscs are widely distributed in both time and space and have a rich and continuous fossil record since Cambrian time. They may be found on sea. There is scarcely and portion of the coast line of the world without Molluscan life. Except in regions of extreme cold. The Molluscs are of diversity from and size. Calcium Carbonate is a major component of Molluscs shells and is available in abundance in marine environments. But other components, particularly protein, are metabolically coastal to produce(Palmer 1983)[7]. Many Molluscs are considered keystone species and lor ecosystem engineers promoting nutrient recycling, soil generation and water filtration (Atkinson *et al* 2013[8]; Gomez-Chiarriet *al* 2015[9]; Schell *et al* 2017[10]; Sun *et al*; 2017[11],Powell *et al.*, 2008)[12]. Shell of molluscs, "chip" is always attraction of collection when one visits sea shore. Molluscs is the Second largest phylum of invertebrate animals. After Arthropoda Members are known as Molluscs. The group has enormous diversity, both in shape and size. Their ecology is also very diversity, for they have been able to live in nearly all kinds of habitat-from the depths of the ocean to some of the highest altitudes recorded for life. In Structure and functional adaptation, molluscs rank with the arthropods because some of the most unique invertebrate behaviour patterns are found among them. Most molluscan live in the sea.Molluscs are among the most ancient, widely diverse and ecological successful group of metazoans. The fossil record of molluscs can be tracked back to the earliest Cambrian period.(Ponder & Lindberg 2008)[13]. The shell has many evolutionary adaptations, such as heavy shells for withstanding stress and pressure, boring and burrowing shell for penetration, swimming shells for locomotion, and reduced shell for preventing encumbrance. Secretion of dorsal shell which in the beginning might have been in the form of layer of cuticle containing calcareous particles and would have served as a protective covering. It is believed, on the basis of biological studies made on molluscs, that all primitive univalves and bivalves had separate sexes, that there were no accessory sexual organs and that the ova and sperm were directly and freely discharged into the seawater. The shell-of ectodermic origin is produced by a group of cell located on the posterior side of larva. These cells field(Kniprath 1981).[14] The Shell is secreted by the mantle. Molluscan have a mantle. Molluscan have a mantle or mass of soft flesh that cover the body and encloses the internal organ.

STUDY AREA

The Present Study was carried out in The District of Nagapattinam lies on the shores of Bay of Bengal between latitude 10.7906°N and Longitude 79.8428°E and area of 1,379 square kilometres (539 sq mi). The District Capital, Nagapattinam lies on the Eastern coast.

Study Site

I have Selected 4 different stations for data collection they are

1. Nagapattinam Coastal Area
2. Akkarapettai Coastal Area
3. Nagore Coastal Area
4. Velankanni Coastal Area

Nagapattinam Coastal Area

Nagapattinam Beach is a famous beach in Tamil Nadu known for its Pristine Sand, Clear blue water and peaceful environment. Nagapattinam is one of the oldest port cities of chola empire. It was called as "Navalpattinam". A coastal district of Tamil Nadu on the eastern coast, Bey of Bengal, 326km, South of the state capital Chennai. The District capital Nagapattinam lies between Northern Latitude 10.7906 degrees and 79.8428 degrees Eastern Longitude.



**Vallipriyadharshini and Sumathi****Akkaraipettai Coastal Area**

Akkaraipettai is a fishing village located in Kelvelur Taluk Nagapattinam district in the State of Tamil Nadu, India. This is surrounded by the water, so called Akkaraipettai. A Majority of the people of Akkaraipettai are employed in sea-borne trading, fishing, Agriculture, Tourism and merchant navy. Coordinates 10.7429°N 79.8490°E.

Nagore Coastal Area

Nagore beach is very calm, small and natural beach. Good for rest and play. Located 6 km from Nagapattinam, Nagore Beach; a popular beach. Nagore beach in Nagapattinam is one of the leading businesses in the Tourist Attraction. Coordinates 10.82°N, 79.85° E.

Velankanni Coastal Area

Velankanni is one of the most visited Pilgrim centres in India. It is a town situated on the shores of Bay of Bengal. Velankanni is special Grade Town in Nagapattinam District in India state of Tamil Nadu. It lies on the coromandel coast of the Bay of Bengal, 12 km of Nagapattinam. Coordinates 10.40°N 79.49°E.

MATERIAL AND METHOD**Study Period**

The Survey and data collection on the population of molluscs from were conducted between November 2023 – February 2024.

Study Area

In order to understand the Molluscan diversity and enlist the Molluscan Population among the coastal wetlands the following Coastal Wetland the following Coastal wetlands (Area) Nagapattinam, Akkaraipettai, Nagore, and Velankanni.

Identification of Gastropods

Gastropods can be recognised by their large foot, tentacles, coiled shell and the presence of torsion, which is where the body is twisted round so that the anus, reproductive organs, mantle cavity, and gills all point forwards.

Identification of Bivalvia

Bivalvia have no head and they lack some usual molluscan organs, like the radula and the Odontophore. Have two hard, usually bowl-shaped, shells, enclosing the soft body.

Collection and preservation of Molluscan Form

Mollusc forms are generally found in the mudflats on the sea shore areas of and estuary the Mollusc have adapted to all habits. Although basically marine. Extensive surveys were conducted in the low total area of sea shore by walk and shells were collected. The collected animals and shells were brought to the laboratory, cleaned and preserved in 5-10% formalin later they were identified up to species level by using the identification of Apte (1998)[15]. Subtleties in the size, direction, number and type of ridges, knobs, folds, striations, crosshatching, spike height or compression, colour markings around the hip or crown. Length of siphon channel, shapes of opening and inner marking or ridges from the fore going discussion it is assembled that to study the different tropical community in order to understanding the dynamic of a habit.

OBSERVATION AND RESULT

The variation among 33 different Molluscan species were identified and also observed. Taxonomically classified and identified all Molluscan Species during Study Period. As Coastal Wetlands are especially important for some present Study has been undertaken to assess the biodiversity in of Molluscan. All the above studies have been carried out in





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the some selected Coastal Area of Some East Coast of India, Nagapattinam, Akkaraipettai, Nagore, Velankanni. Variations in Temperature, Chemical Properties of water are observed in sea Wetlands during the study period. Totally 33 different Species of Molluscan Shell species observed in Wetlands studies, the Molluscan was identified by Common Name, Scientific Name, Order, Family and Characters group and habitat. They are Eight Order viz, Caenogastropoda, Littorinimorpha, Neogastropoda, Trochida, Pectinida, Cardiidae, Venerida, Mesogastropoda and Twenty four Families viz, Turritellidae, Stombidae, Rostellariidae, Muricidae, Fasciolaridae, Turbinidae, Cypracidae, Pectinidae, Busyconidae, Anomidae, Cardiidae, Solecurtidae, Harpidae, Cassidae, Turbinellidae, Babalonidae, Fidae, Conidae, Donacidae, Drilliidae, Tonnidae, Veneridae, Architectonicidae, Naticidae. These Molluscan Species were Classified into Four Basis Foot, Mantle, Shell and Visceral mass. Among them 13 Species belong to Order Neogastropoda, 9 Species of Littorinimorpha, 4 Species of Pectinida, 3 Species of Cardiida, 1 Species to Caenogastropoda, Trochida, Veneridae, Mesogastropoda. All the Molluscan Species are Classified to the Taxonomic family which 3 Species Turbinidae, Pectinidae, Cassidae, 2 Species Muricidae, Turbinidae, Babyloniidae, 1 Species to Turritellidae, Stombidae, Rostellariidae, Fossicotarridae, Cypraeidae, Busyconidae, Anomidae, Cardiidae, Solecurtida, Harpidae, Fidae, Conidae, Donacidae, Drilliidae, Tonnidae, Veneridae, Architectonicidae, Naticidae. The present study on the Molluscan Population is due to some environment changes. After that resident and local resident Molluscan Species. Hence it is suggested in future research studies would provide valuable information and relationship between play a role the variation of Biodiversity

DISCUSSION

The Present study documented 33 Species of Molluscs among 25 Gastropoda Species, 8 Bivalvia Species, were identified from different habitat around Nagapattinam Coastal Area. Ecologically to this important group (Fabry *et al.*, 2008)[16]. With Their organism nested deeply with in Ediacaran Molluscan have a lively and fascinating evolutionary history. Recent Advantages in palaeontological, Phylogenetic Development and experimental approach have revealed some of mysteries revolving around the emergence of large phenotypic diversity encountered in modern and fossil species (Perry & Henry 2015)[17]. The higher diversity of gastro, Molluscs provide essential ecosystem services including habitat structure. For benthic organism, act as biological filter to purify polluted estuarine water are a good a for other organism. The conservation of Biological Diversity requires the Inclusion of biodiversity in Environmental Assessment, since recommended to devote more effort to repeated measurement is space and time than to a few sites on a short timescale (Costello *et al.*, 2004)[18]. Several Studies focused on the Molluscan fauna have been carried out in worldwide continental shelves. Algae or seagrass meadows, maerl and other hard substrate types tend to be richer in species than soft-bottom (Riera *et al.*, 2012)[19]; Urra *et al.*, 2013)[20]. Thus Molluscs have been used as community surrogates in these ecosystem because they are a group of animals with a wide ecological spectrum and which use a considerable portion of environmental resources due to their distribution and diversity, furthermore, they are important in food chains because they can be detritivores, herbivores, carnivores or omnivores (Levinton 1995)[21]. A number of studies have been conducted on various biological aspects Molluscs, along with Biodiversity and distribution patterns (Lowry *et al.*, 1974)[22]. The Mollusca diversity of Great Nicobar island (Arumugamet *et al.*, 2010)[23] and biodiversity of Barren island – Chandra and Rajan 2010)[24] were also studied recently. Among Various functions that shells may play, defence against predators is considered that most important from an evolutionary point of view (Vermeij, 1987)[25].

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Table 1: List of Molluscan Species (Gastropoda) recorded in Nagapattinam Coastal Area

S.No.	COMMON NAME	SCIENTIFIC NAME	ORDER	FAMILY
1.	Tower shell	<i>Turritellacommunis</i>	Caenogastropoda	Turritellidae
2.	Variable stromb	<i>Canariummutabile</i>	Littorinimorpha	Stocombidae
3.	Spindle tibia	<i>Tibia fusus</i>	Littorinimorpha	Rostellariidae
4.	Murex	<i>Murex pectin</i>	Neogastropoda	Muricidae
5.	Forceps	<i>Fusinus forceps</i>	Neogastropoda	Fasciotariidae
6.	Asian rapa whelk	<i>Rapanvenosa</i>	Neogastropoda	Muricidae
7.	Green Turban	<i>Turbo marmoratus</i>	Trochida	Turvinidae
8.	Tiger Cowrie	<i>Cypaeatigris</i>	Neogastropoda	Cypraeidae
9.	Channeled whelk	<i>Busycotopuscanaliculatus</i>	Neogastropoda	Busyconidae
10.	Articulate harp shell	<i>Harpaarticularis</i>	Neogastropoda	Harpidae
11.	Japanese bonnet	<i>Semicassisbisulcata</i>	Littorinimorpha	Cassidae
12.	Lamp Shell	<i>Turbinellaalgalulada</i>	Neogastropoda	Turbinellidae
13.	Gaint Spider conch	<i>Lambis truncate</i>	Littorinimorpha	Stombidae
14.	Chank Shell	<i>Xancuspyrum</i>	Neogastropoda	Turbinellidae
15.	Spiral Babylon	<i>Babylonia spirata</i>	Neogastropoda	Babyloniidae
16.	Paper Fig shell	<i>Ficusficus</i>	Littorinimorpha	Ficidae
17.	Gradvated Cone	<i>Conus gradates</i>	Neogastropoda	Conidae
18.	Virginmorex	<i>Chicoreusvirgineus</i>	Neogastropoda	Muricidae
19.	Japanese Babylon	<i>Babylonia zeylanica</i>	Neogastropoda	Babyloniidae
20.	Turrid shell	<i>Clavusbilinealus</i>	Neogastropoda	Drilliidae
21.	Spotted Tun	<i>Tonnadolum</i>	Littorinimorpha	Tonnidae
22.	Grey bonnet	<i>Phaliunglacum</i>	Littorinimorpha	Cassidae
23.	Rogosebonnet	<i>Galeodearugose</i>	Littorinimorpha	Cassidae
24.	Perspectivesundial shell	<i>Architectonicaperspectiva</i>	Mesogastropoda	Architectonicidae
25.	Moon shell	<i>Neveritajosephinia</i>	Littorinimorpha	Naticidae










Table 2: List of Molluscan Species (Bivalvia) recorded in Nagapattinam Coastal

S.NO.	COMMON NAME	SCIENTIFIC NAME	ORDER	FAMILY
1.	Coquina Shell	<i>Donexvariabilie</i>	Cardiida	Donacidae
2.	Great Scallop	<i>Pectenmaximus</i>	Pectinida	Pectinidae
3.	Jingle shell	<i>Anomia simplex</i>	Pectinida	Anomiidae
4.	Cockle	<i>Cerasstidermaedule</i>	Cardiidae	Cardiidae
5.	Mediterranean Scallop	<i>Pectenjacobaesus</i>	Pectinida	Pectinidae
6.	Lesser Tagelus	<i>Tagelussubterres</i>	Cardiida	Solecurtidae
7.	Caepetclam	<i>Paradapestextilis</i>	Venerida	Veneridae
8.	Atlanticalico scallop	<i>Argopectengibbus</i>	Pectinida	Pectinidae

















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TOWER SHELL (<i>Turritella communis</i>)	VARIBLE STROMB (<i>Canarium mutabile</i>)
	
SPINDLE TIBIA (<i>Tibia fusus</i>)	MUREX (<i>Murex pectin</i>)
	
FORCEPS (<i>Fusinus forceps</i>)	ASIAN RAPA WHEL (<i>Rapanvenosa</i>)
	
GREEN TURBAN (<i>Turbo marmoratus</i>)	TIGER COWRIE (<i>Cypaeatigris</i>)
	
CHANNELED WHELK (<i>Busycotopus canaliculatus</i>)	ARTICULATE HARB SHELL (<i>Harpaarticularis</i>)






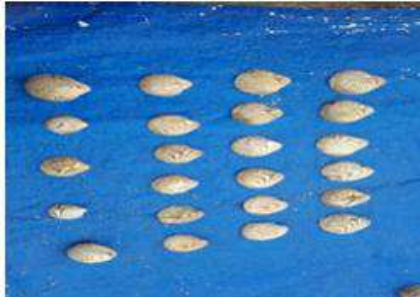





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JAPANESE BONNET (<i>Semicassis bisulcata</i>)	LAMP SHELL (<i>Turbinella argulada</i>)
	
PAPER FIG SHELL (<i>Ficus ficus</i>)	GRADUATED CONE (<i>Conus gradates</i>)
	
VIRGIN MOREX (<i>Chicoreus virgineus</i>)	GREY BONNET (<i>Phalium glaucum</i>)
	
JAPANESE BABYLON (<i>Babylonia zeylanica</i>)	SPOTTED TUN (<i>Tonnadolum</i>)
	
MOON SHELL (<i>Neverita josephina</i>)	ROGOSE BONNET (<i>Galeodearugose</i>)
	
PERSPECTIVE SUNDIAL SHELL (<i>Architectonica perspectiva</i>)	TURRID SHELL (<i>Clavus bilineatus</i>)
FIGURE:1 GASTROPODA	





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GREAT SCALLOP (<i>Pecten maximus</i>)	JINGLE SHELL (<i>Anomia simplex</i>)
	
COCKLE (<i>Cerastoderma edule</i>)	ATLANTIC CALICO SCALLOP (<i>Argopecten gibbus</i>)
	
MEDITERRANEAN SCALLOP (<i>Pecten jacobaeus</i>)	COQUINA SHELL (<i>Donax variabilis</i>)
	
CAEPET CLAM (<i>Paradapetextilium</i>)	LESSER TEGELUS (<i>Tagelus subterres</i>)
FIGURE:2 BIVALVIA	





Physicochemical Evaluation and GC-MS Analysis of Infused Oil from Medicinal Plants – *Mangifera indica* L. and *Piper betle* L.

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ABSTRACT

Macerated oil is prepared by infusing desired plant parts in a carrier or base oil of interest that could be either sunflower oil, sesame oil, olive oil or coconut oil for a specific period of time. This infusion is packed with enormous medicinal compounds that is being widely utilized in many pharmaceutical applications such as in aromatherapy, healing as they do not exhibit any toxic or side effects since, their preparation is devoid of chemicals and enriched only with natural compounds. It is also referred to as "Infused oil" and is known to possess numerous biological properties as a result of active compounds derived from plants. In the present study, Infused oil was prepared using dried plant leaf samples from *Mangifera indica* L. and *Piper betle* L. The carrier or base oil used in this preparation is Virgin Coconut oil. Infused oil was prepared by two methods – a) With heating (+H) and b) Without heating method (-H). The corresponding weight of infused oil was calculated. Physicochemical properties such as acid value, saponification value, ester value, free fatty acid value, insoluble impurities were evaluated and determined for the presence of fatty acid components in the oil by GC-MS analysis.

Keywords: Infused oil, Medicinal plants, Active compounds, Carrier oil, Physicochemical properties, GC-MS analysis.





INTRODUCTION

Bioactive compounds from plant sources encompass innumerable therapeutic properties and their functions vary with polarity i.e., From highly polar to highly non polar components each with a unique biological activity. These plant metabolites can be extracted through various techniques and one among these is maceration or also referred to as infusion. Infusion is the process wherein the powdered plant parts are kept immersed in the desirable solvent or carrier oil for a certain period of time allowing the complete extraction of phytocomponents into it and is suitable for delicate tissues like flowers, leaves and soon. [1]. Herbal oil thus prepared by infusion contains maximum number of beneficial compounds derived from plants along with the fatty acids in carrier oil thereby elevating the efficacy of oil for usage in wide therapeutic applications. Infused oil derived from plant source has been widely used since ancient times in treating inflammatory conditions [2] and are utilized in the form of medicines, perfumes, stabilizing agents, as disinfectants and so... [3]. They are also reported to play a vital role in pharmacological applications as antioxidants, in treating harsh skin conditions and hair fall, in healing wounds, reducing sprains and inflammation. The properties of herbal infused oil could also be further enhanced with the addition of ingredients like flavours, aromatic compounds and fragrances, gel/ ointment base depending upon the nature of usage. Assessment of oil quality is important in determining the purity, stability and suitability of oil for usage in various applications and can be evaluated based on their physicochemical properties [4,5]. Infused herbal oil can be prepared by means of either hot infusion method or cold infusion method i.e., with heat or without heat. However, the nature of carrier oil used, method of extraction and temperature employed also plays an important role in imparting the properties to the final product. In the current scenario, plant derived oils are gaining more attention and importance in the pharmaceutical industry since they are naturally derived, cost effective, safe and could have less or no negative impacts on our health. Virgin coconut oil contains fatty acids such as palmitic acid, myristic acid, linoleic acid, that have specific functional as well as medicinal properties [6]. They are also reported to contain high amount of phenolic compounds exhibiting antiproliferative activity, anticancer activity and also, used traditionally in treating hair and skin conditions [7]. The present study deals with preparation of infused oil from leaf samples of two medicinal plants *Mangifera indica* L. and *Piper betle* L. The dried and powdered plant leaf samples were infused in Virgin coconut oil as the carrier oil employing both the methods of, with heating (+H) and without heating (-H). Weight of infused oil obtained along with their physicochemical properties such as acid value, saponification value, ester value, free fatty acid value, insoluble impurities were evaluated. Bioactive components present in the oil samples were also determined by means of Gas Chromatography – Mass Spectrometric (GC-MS) analysis.

MATERIALS AND METHODS

Collection and authentication of Samples

Leaf samples of two medicinal plants *Mangifera indica* L. and *Piper betle* L. were collected from different localities and authenticated by Prof P. Jayaraman, Director, Plant Anatomy Research Centre (PARC), West Tambaram, Chennai. The collected samples were cleaned, dried, powdered and stored at 4°C until further use.

Preparation of Infused oil

Infused oil was prepared using the powdered leaf samples of *Mangifera indica* L. and *Piper betle* L. employing 2 methods.

With heating (+H)

About 5 grams of dried plant leaf samples were added individually to 50 ml of virgin coconut oil taken in a conical flask in the ratio of 1:10. The samples were heated on water bath at 60°C for about 30 minutes to allow complete infusion. It was then cooled and filtered. Infused oil thus obtained was stored in bottles at 4°C.





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Without heating (-H)

About 5 grams of dried plant leaf samples were added to 50 ml of virgin coconut oil taken in a glass bottle in the ratio of 1:10. It was covered and incubated for about a week at room temperature with frequent shaking to allow complete infusion. The oil was filtered and stored in bottles at 4^o C.

Determination of Weight (g) of Infused oil

Weight (g) of infused oil obtained by both the methods: With heating (+H) and Without heating (-H) was calculated using the formula:

Weight of Infused oil [g] = Weight of beaker + Oil [W₂] – Weight of Empty beaker [W₁]

Physicochemical Properties of Infused oil

Physicochemical properties of Infused oil such as Acid value, Saponification value, Ester value, Free Fatty acid (FFA) value and Insoluble impurities were determined [8-13].

Preparation of Fatty acid Methyl esters (FAME)

FAME preparation was carried out by means of Base catalyzed derivatization method. 2g oil sample was mixed with 16ml of 0.5M Methanolic KOH solution and heated at 50°C for 20 secs. 40 ml hexane was added and vortexed for 30 secs. It was allowed to settle and the top layer was collected. To that, about 16ml of 2N Methanolic HCL was added and vortexed. The solution was allowed to settle and the top layer collected was used for further GC-MS analysis [14].

GC-MS analysis

Gas Chromatography – Mass Spectrometry (GC-MS) analysis for the Fatty acid Methyl esters [FAME] of Infused oil from *Mangifera indica* L. and *Piper betle* L. was carried out using GC-MS Shimadzu QP2020 instrument with SH-RXi-5Sil MS Column and Helium as the flow gas. The conditions followed for GC-MS analysis was given - Column Oven Temperature: 50.0 °C, Injection Temperature: 250.00 °C, Pressure: 68.1 kPa, Total Flow: 16.2 mL/min, Column Flow: 1.20 mL/min, Linear Velocity: 39.7 cm/sec, Purge Flow: 3.0 mL/min, Split ratio: 10.0, Ion source temperature: 200.00 °C and Interface temperature: 250.00 °C. Oven Temperature Program was maintained as follows:

Rate	Temperature (°C)	Hold Time (min)
-	50.0	0.00
6.00	280.0	2.00

Spectrums of the components were compared with the database of spectrum of known components stored in the GC-MS NIST and WILEY library.

RESULTS AND DISCUSSION

Infused oil Preparation

Infused oil was prepared using the dried and powdered leaf samples of *Mangifera indica* L. and *Piper betle* L. with Virgin Coconut oil as base employing 2 methods: With heating (+H) and Without heating (-H). Weight (g) of Infused oil was calculated for about 50ml of oil sample. The weight of infused oil obtained was found to be higher in samples prepared with heating (+H) than samples prepared without heating (-H). Among the oil samples prepared by heating (+H) method, *Mangifera indica* L. showed higher yield with 45.793 g followed by *Piper betle* L. with 45.077 g [Figure 1].

Determination of Physicochemical properties of Infused oil

Physicochemical properties such as Acid value, Saponification value, Ester value, Free fatty acid value and Insoluble impurities were determined to understand the quality and efficacy of infused oil for therapeutic applications. Acid value is calculated as mg KOH / g oil and it indicates the quality of oil. Acid value was found to be higher in infused oil prepared without heating method (-H). Among the (-H) samples, *Piper betle* L. showed higher acid value with 5.049 mg KOH/g oil followed by *Mangifera indica* L. with 4.488 mg KOH/g oil while, samples prepared with heating





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method (+H) showed lower acid value with *Piper betle* L. having 2.244 mg KOH/g oil and *Mangifera indica* L. with 1.683 mg KOH/g oil [Figure 2]. Acid value determines the quality of oil wherein, higher acid value indicates deterioration of oil quality while, lower acid value indicates good quality of oil[15]. Saponification value is expressed as mg KOH/g oil and was found to be higher in oil prepared with heating method (+H) showing increased value in *Mangifera indica* L. with 424.022 mg KOH/g oil and *Piper betle* L. with 396.907 mg KOH/g oil while, oil prepared without heating method (-H) showed lower Saponification value for *Mangifera indica* L. with 337.067 mg KOH/g oil and *Piper betle* L. with 317.432 mg KOH/g oil [Figure 3]. Higher saponification value indicates short chain fatty acids with lower molecular weight that can be easily saponified and indicates good quality of oil while, low saponification value indicates long chain fatty acid with higher molecular weight that cannot be saponified [16]. Ester value is calculated as the difference between saponification value and acid value and is expressed as mg KOH/g oil. Ester value was found to be higher in infused oil prepared with heating method (+H) than the oil samples prepared without heating (-H). Among the oil samples prepared by heating (+H), *Mangifera indica* L. showed higher ester value of 422.339 mg KOH/g oil followed by *Piper betle* L. with 394.663 mg KOH/g oil [Figure 4]. Free fatty acid value was found to be lower in samples prepared with heating (+H) method compared to the samples prepared without (-H) heating. Among the (+H) samples, *Mangifera indica* L. showed Free Fatty acid value of 0.841 and *Piper betle* L. with 1.121 respectively [Figure 5]. Insoluble impurities were also found to be slightly lower in the (+H) samples compared to the (-H) samples. Among the (+H) samples, *Piper betle* L. showed 0.064 g while, *Mangifera indica* L. had 0.049 g insoluble impurities/ g oil [Figure 6]. Based on the yield obtained and its physicochemical properties, Infused oil prepared with heating method (+H) was selected and subjected to GC-MS analysis in order to determine the presence of bioactive components in the oil extracted from the plant samples.

GC-MS analysis

GC-MS analysis was carried out for the infused oil sample prepared using *Mangifera indica* L. and *Piper betle* L. Based on the physicochemical analysis, oil prepared by heating method (+H) was further subjected to Base catalyzed derivatization method and the fatty acid components in the infused oil were determined by means of GC-MS analysis. GC-MS Chromatogram of oil samples are given in Figures 7 and 8. *Mangifera indica* L. infused oil showed the presence of totally 21 compounds with corresponding retention time such as (1) Octanoic acid, Methyl ester [9.665]; (2) Cyclohexasiloxane, dodecamethyl- [13.857]; (3) Decanoic acid, Methyl ester [14.32]; (4) 1,3-Diphenyl-1-((Trimethylsilyl)oxy)-1(Z)-Heptene [17.467]; (5) Dodecanoic acid, Methyl ester [18.598]; (6) Tri-O-Trimethylsilyl, N-Pentafluoropropionyl derivative of Terbutaline [20.701]; (7) Tetradecanoic acid, Methyl ester [22.45]; (8) Phosphonous dibromide, [2,2,2-Trifluoro-1-(Trifluoromethyl)-1-[(Trimethylsilyl)oxy] Ethyl]- [23.497]; (9) Hexadecanoic acid, Methyl ester [25.938]; (10) (Z,Z)-Heptadeca-8,11-Dien-1-yl bromide [28.605]; (11) 9-Octadecenoic acid, Methyl ester [28.714]; (12) Octadecanoic acid, Methyl ester [29.119]; (13) Diisooctyl phthalate [34.753]; (14) 2,5-Dimethyl-1,3,5-Dithiazine [36.126]; (15) Methyl 3-Methyl-5-Oxy-2-Phenoxyhexanedithioate [38.742]; (16) 2-Fluoro-5-trifluoromethylbenzoic acid, propyl ester [38.88]; (17) N- {2- [2'- (5'' - Chloro - 1'' - Oxopentyl) - 4', 5'-Dimethoxyphenyl] Ethyl} Chloroethanamide [38.945]; (18) Ethyl 2-Cyano-2-(P-Methoxyphenyl)-3-Methylpentanoate [38.995]; (19) 4-Methyl-1H-Pyranolo [4,3-C] Pyridine [39.26]; (20) 14,19-Dioxoundecacyclo [9.9.0.0 (1,5). 0(2,12). 0(2,18). 0(3,7). 0(6,10). 0(8,12). 0(11,15). 0(13,17). 0(16,20)]icosane-4-syn, 9-syn-dica [40.055] and (21) 4-Methyl-1H-Pyranolo [4,3-C] Pyridine [40.207] [Figure 7]. *Piper betle* L. infused oil showed the presence of totally 19 compounds with corresponding retention time such as (1) Octanoic acid, Methyl ester [9.664]; (2) Cyclohexasiloxane, dodecamethyl- [13.859]; (3) Decanoic acid, Methyl ester [14.32]; (4) 1,3-Diphenyl-1-((Trimethylsilyl)oxy) -1(Z) -Heptene [17.467]; (5) Dodecanoic acid, Methyl ester [18.598]; (6) Tri-O-Trimethylsilyl, N-Pentafluoropropionyl derivative of Terbutaline [20.701]; (7) Tetradecanoic acid, Methyl ester [22.45]; (8) Hexadecanoic acid, Methyl ester [25.939]; (9) (Z,Z)-Heptadeca-8,11-Dien-1-yl Bromide [28.608]; (10) 9-Octadecenoic acid, Methyl ester [28.714]; (11) Octadecanoic acid, Methyl ester [29.12]; (12) 1,2-Benzenedicarboxylic acid, Dioctyl ester [34.753]; (13) 6,6-Dimethyl-9-Methylenebicyclo [3.3.1] Nonan -3-one [36.127]; (14) 1,4-Diphosphorin, 1,4-Dihydro-1-Phenyl-4-(Phenylmethyl)-, Cis- [39.02]; (15) Methyl 3-Methyl-5-Oxy-2-Phenoxyhexanedithioate [39.173 and 39.883]; (16) 1,8-Naphthalenediol, 1, 2, 3, 4, 4A, 5, 8, 8A-Octahydro - 4, 4, 8A-Trimethyl-6-(Phenylthio)-, (1. Alpha., 4A. Beta., 8. Alpha., 8A. Alpha.)- [39.599]; (17) Ethyl (1R*, 2S*, 11R*) - (+)-3,10-Dioxo-2,11-Epoxy cyclodecane-1-Carboxylate [39.705]; (18) Butanedioic acid, 2-Ethyl-2-(Phenylthio)-, 1-Ethyl ester [39.995]; (19) Benzamide, 2-Methyl-3,5-Dinitro- [40.185] [Figure 8].





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CONCLUSION

Plant based oil have enormous benefits that can be utilized for various therapeutic purposes. In this study, Infused oil prepared from the dried leaf samples of *Mangifera indica* L. and *Piper betle* L. were analyzed for their physicochemical properties and also determined for the presence of bioactive components by means of Gas Chromatography – Mass Spectrometry [GC-MS] analysis. Further studies can be carried out to explore the pharmacological importance of infused oil and their bio component based drugs in treating various diseases.

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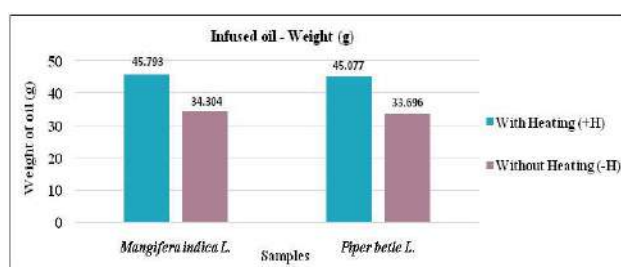


Figure.1: Weight of Infused oil

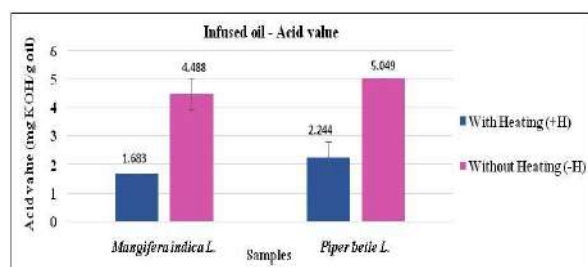


Figure.2: Acid value of Infused oil

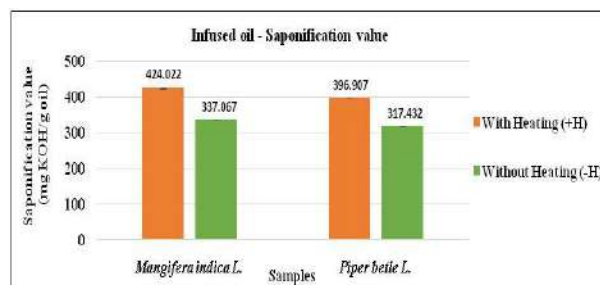


Figure.3: Saponification value of Infused oil

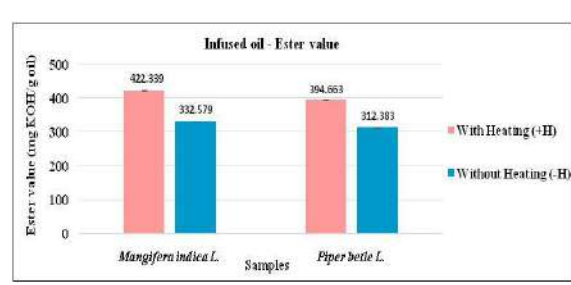


Figure.4: Ester value of Infused oil

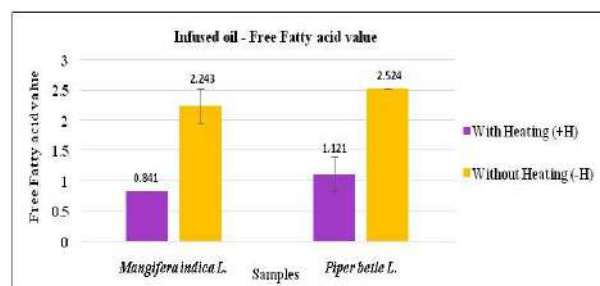


Figure.5: Free Fatty acid value of Infused oil

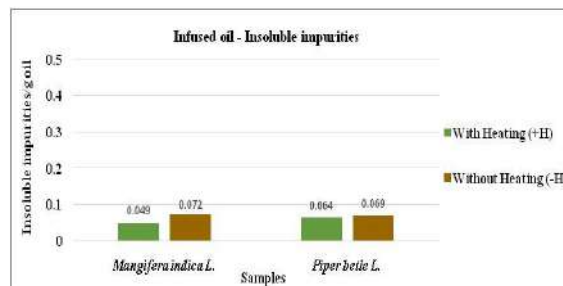


Figure.6: Insoluble impurities in Infused oil





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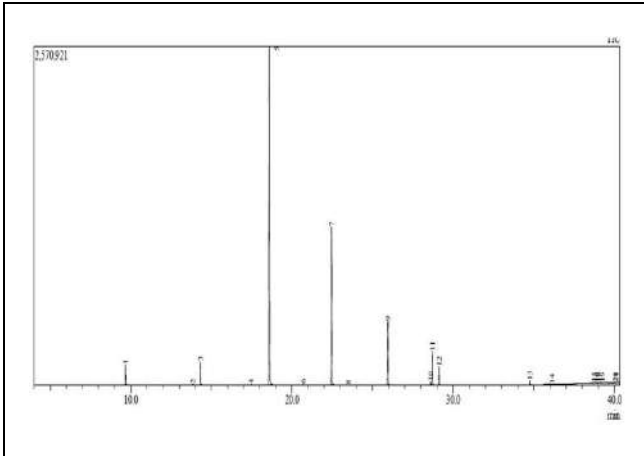


Figure.7: GC-MS Chromatogram of *Mangifera indica* L.
Infused oil (+H)

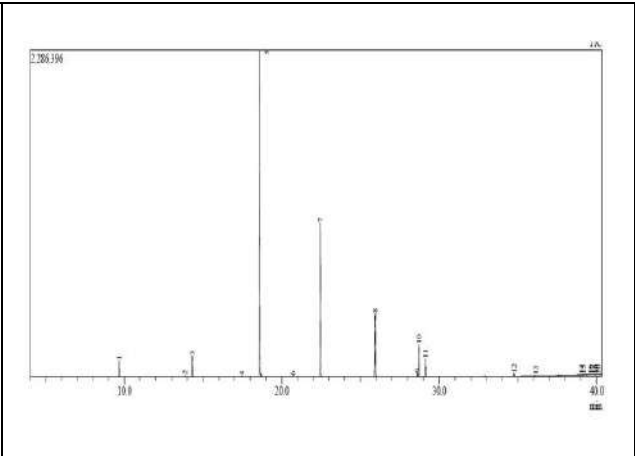


Figure.8: GC-MS Chromatogram of *Piper betle* L.
Infused oil (+H)





A Comprehensive Review of Limonene: Exploring its Biosynthesis, Ecological Impact and Aromachological Aspects

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ABSTRACT

Limonene is widely recognized as one of the most prevalent compounds in the essential oils derived from aromatic plants. Its presence as a monoterpene hydrocarbon in diverse plant genera can be attributed to its precursor role in the biosynthesis of other monoterpenes and its defensive capabilities against herbivores. The extensive investigation of limonene is attributed to its medicinal potential and its roles in the flavor and fragrance industries. This paper seeks to provide a comprehensive overview of the biosynthetic, ecological, and aromachological relevance of limonene, consolidating prominent insights from diverse studies into a brief review.

Keywords: Limonene, monoterpene, aromachology, bioconversion, biosynthesis

INTRODUCTION

Limonene, scientifically designated as 1,8-p-menthadiene or 1-methyl-4-(1-methylethenyl-cyclohexene), ranks among the most prevalent constituents of essential oils derived from aromatic plants. Its presence is widespread across various plant genera, which can be attributed to its role as a precursor for numerous monocyclic monoterpenoids. Many monoterpenes that feature the 1-*p*-menthene skeleton, including carveol, carvone, α -terpineol, pulegone, and 1,8-cineole, originate from limonene (Kjonaas and Croteau, (2003); Berteau et al.(2003). This compound exhibits optical



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activity and exists in two enantiomeric forms, namely R and S. The R-(+)-enantiomer, commonly referred to as d-limonene, predominates in the essential oils extracted from the peels of citrus species, while (+)-limonene is a cost-effective byproduct of orange processing (Arreola et al. (2005); Wang et al. (2008)). Furthermore, it is frequently found in certain species of *Lippia* and *Artemisia* (Gurgel do Vale et al., (2002); Sayyah et al., (2004). Conversely, Kokkini et al., (1996) reported that the l-limonene is primarily located within the essential oils of *Pinus*, such as those from pine needles, and *Mentha* species, including spearmint. Limonene is frequently added to many products to improve flavor and fragrance, including perfumes, drinks, soaps, detergents, and cleaning products. It also serves as a starting material for making other natural products like p-cymene. Taking into account the considerable amount of reports, its potential health benefits, and its use in cosmetics and household products, it's crucial to compile research on this important substance.

Biosynthesis of limonene in plants

Limonene is synthesized from geranyl pyrophosphate, following a pathway that includes a stable cationic intermediate, leading to the production of limonene along with other monoterpenes (Mann et al. (1994). The process of hydroxylation of limonene occurs at the C3 position via cytochrome P450, leading to the generation of (–)-trans-isopiperitenol, or alternatively, it can be hydroxylated at the C6 position to yield (–)-trans-carveol. Furthermore, carveol is subject to a dehydrogenation reaction that transforms it into the monoterpenoid carvon (Croteau et al. (1991). The transformation of carveol to carvone may be attributed to stability, with the formation of a conjugated cyclic ketone serving as the primary driving force for this reaction. This process may, among other factors, account for the relatively low concentrations of carveol found in many essential oils. Monoterpenoids that originate from limonene, including carvone and 1,8-cineole, are the predominant compounds in the essential oils extracted from *Mentha* and *Eucalyptus* species, respectively. The study by Kokkini et al. (1996) revealed that several *Mentha* species have essential oils with high carvone content, ranging from 50% to over 75% and limonene levels ranging from 3% to 20%. Elss et al. (2007) indicated that under acidic storage conditions, limonene-rich juices can convert some limonene into α -terpineol and carvone, depending on the oxygen levels. They also noted that a considerable amount of limonene comes from the essential oils of oven-dried *M. longifolia* leaves. Asekun et al. (2007) conducted a comparative analysis of the chemical compositions of essential oils from leaves treated in various ways, revealing that fresh leaves were predominantly rich in pulegone (35%), whereas the oils from oven-dried leaves were characterized by a higher concentration of limonene (40.8%). This finding supports the earlier research conducted by Lange et al. (2000), which indicated that limonene acts as a precursor in the biosynthesis of pulegone within the glandular trichomes of *Mentha* species.

Microbial conversion of limonene into oxygenated derivatives:

In recent days, there has been a notable increase in research focused on the biotechnological production of aroma molecules derived from monoterpenes like limonene as a result of the escalating demand for 'natural' fragrance materials in the flavor and fragrance markets (Chotani et al. 2000). The current focus is on employing microorganisms as biological vehicles for converting limonene and other monoterpenes into diverse oxygenated derivatives. This microbial biotransformation of monoterpenes is advantageous due to its ease of manipulation, the ability to operate under mild reaction conditions, high efficiency, and regio- and stereoselective outcomes (Houjin et al. 2006). The initial documentation of bioconversion can be traced to the 1960s, during which limonene underwent microbial conversion, resulting in the formation of several neutral and acidic compounds (Dhavalikar and Bhattacharya, (1966). Numerous studies have since emerged that explore the use of microbes for the bioconversion of limonene into a range of derivatives. *Pseudomonas incognita* and *P. gladioli* were among the pioneering bacterial species utilized in limonene metabolism studies. *P. incognita* has been found to metabolize limonene into dihydrocarvone, carvone, and carveol, while *P. gladioli* is known for converting limonene into α -terpineol and perillic acid (Cadwallader et al. (1989 and 1992). α -Terpineol is prevalent in natural sources and plays a significant role in the perfumery market. The research conducted by Duetz et al. (2001) indicates that soil microorganisms such as *Rhodococcus opacus* and *R. globerulus* have been utilized in bioconversion research. In contrast to the *Pseudomonas* assays, the *Rhodococcus* species demonstrated superior limonene metabolism, resulting in high yields of end products. In a chemostat culture where toluene served as the carbon and energy source, *R. opacus* exhibited both



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regioselectivity and stereospecificity in its conversion of limonene, exclusively hydroxylating the C6 carbon to produce enantiomerically pure (+)-trans-carveol with a yield of 97% and trace amounts of carvone. Conversely, *R. globerulus* displayed limited activity in a separate bioconversion, further oxidizing much of the generated trans-carveol into (+)-carvone. In addition, Hamada et al. (2003) indicated that the stereo- and regioselective hydroxylation of limonene has been successfully performed using the *Cyanobacterium*, *Synechococcus elongatus* PCC 7942. Following a six-hour incubation, the microorganism hydroxylated the allylic position (C6) of the endocyclic C=C double bonds of (S)-(-)-limonene, yielding cis- and trans-carveol at 11% and 9% yields, respectively. In contrast, under the same experimental conditions, (R)-(+)-limonene did not convert into its respective products, demonstrating a clear differentiation between the (S)- and (R)-stereoisomers of limonene. The promising bioconversion of limonene into various monoterpenes through the use of soil bacterial strains has stimulated additional research into the potential of other bacterial species. Subsequent studies have also highlighted biotechnological advancements, including the examination of plant gene expression within selected bacterial cells and Organisms such as *Escherichia coli* and *Saccharomyces cerevisiae* have been employed in modified bioconversion processes. According to Carter et al. (2003) and Haudenschield et al. (2000), the conversion of limonene to carvone and other derivatives using *E. coli* has proven to be less efficient in comparison to *Pseudomonas* species. Nonetheless, products like carvone have been successfully Furthermore, several fungal species have exhibited the ability to metabolize limonene into a range of derivatives. The first documented instance of successful bioconversion was reported by Kraidman et al. (1969) and Mukherjee et al. (1969) during the late 1960s, where a *Cladosporium* species referred to as T7 converted limonene into trans-limonene-1,2-diol. As stated by Mukherjee et al. (1973), the fungus *Cladosporium* can convert limonene into α -terpineol.

According to the findings of Mattison et al. (1971), the interaction of limonene with *P. italicum* and *P. digitatum* resulted in the production of trans-carveol (26%) as the predominant compound, along with (+)-carvone (6%) and various minor constituents. This discovery has generated significant interest in further exploring the metabolism of monoterpenes by *Penicillium* species. The research conducted by Tan and Day (1998) revealed that immobilized *P. digitatum*, when cultivated in submerged liquid cultures, effectively transformed (R)-(+)-limonene into (R)-(+)- α -terpineol. This transformation was similarly observed in studies examining the effects of organic co-solvents on the bioconversion of limonene to α -terpineol. Demyttenaere et al. (2001) demonstrated that the yield of α -terpineol can be effectively enhanced through the parallel application of sporulated surfaces and liquid cultures of *Penicillium* species. The findings of this assay revealed that *P. digitatum* produced the most compelling results, particularly in terms of its efficient recovery of α -terpineol. A subsequent experiment, in which the same microbe was allowed to metabolize a substrate for a period of 8 hours, resulted in an impressive recovery rate of up to 100% of α -terpineol. It was also established that the efficiency of substrate metabolism (specifically limonene) was influenced by the characteristics of the *P. digitatum* strain, the type of cosolvent used, and its concentration. Other fungal species evaluated in limonene bioconversion assays include *Aspergillus niger*, *A. cellulosa*, *Corynespora cassiicola*, and *Diplodia gossypina* (Abraham et al. (1986) Noma et al. (1992). The primary rationale for selecting limonene as the precursor for bioconversions has consistently been its abundant availability in its pure enantiomeric form and its cost-effectiveness.

Biosynthesis of natural products by using Limonene

The synthesis of natural products has consistently presented significant challenges, particularly concerning the starting materials, as many chemical compounds utilized may be toxic or potentially carcinogenic. For instance, the large-scale synthesis of p-cymene has traditionally relied on benzene combined with methyl and isopropyl halides in the presence of $AlCl_3$ as a Lewis acid catalyst, or alternatively, toluene with isopropyl alcohol. These reactions exhibit low selectivity, yielding both ortho and para isomers, necessitating additional separation processes. Increasingly stringent environmental regulations are limiting the use of these chemical compounds, highlighting the necessity for eco-friendly reagents in the synthesis of p-cymene. Limonene has emerged as a significant advancement in the search for safe, non-toxic starting materials for this natural product's synthesis. Its six-membered ring structure can be easily aromatized, making it a viable alternative to hazardous aromatic intermediates like benzene and toluene. This is supported by research conducted by Martín-Luengo and colleagues (2008), who utilized limonene as a precursor in the synthesis of p-cymene. The conversion was performed under solvent-free conditions using mesoporous silica-alumina supports and microwave irradiation, achieving a remarkable selectivity of 100% and high yields in a brief



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time frame. Specifically, a complete conversion of limonene to p-cymene was accomplished with Siral 40 (silica gel with a designated content of 40) in just 10 minutes. This illustrates a rapid and efficient conversion process suitable for p-cymene production. The high efficiency and selectivity present manufacturers with an attractive alternative to the traditional Friedel-Crafts alkylation methods involving benzene or toluene. p-Cymene is a crucial aromatic compound utilized in the synthesis of fine chemicals, which are essential for producing fragrances, flavoring agents, herbicides, pharmaceuticals, and p-cresol. Soung et al. (2000) have reported that limonene is effectively employed in the synthesis of natural products, particularly in the formation of β - and γ -thujaplicins. These compounds were first isolated from *Chamaecyparis taiwanensis* and *Thuja plicata*, where they were classified as naturally occurring monocyclic tropolones. Their importance as antibacterial and antifungal agents has led to increased interest in developing synthetic routes for their manufacture. The regioselective synthesis of β -thujaplicin and γ -thujaplicin from (R)-(+)-limonene involved several dienyl silyl ether intermediates, achieving yields of up to 18% and 22%, respectively, through 11 and 10 synthetic steps. The availability and affordability of (R)-(+)-limonene further reinforce its role as a key precursor for the synthesis of effective antimicrobial natural products.

Ecological aspects of limonene

Langenheim, (1994) indicated that limonene plays a significant ecological role in plants, functioning as an antifeedant within their defense mechanisms, exhibiting antifungal properties, and serving as an attractant for pollinators. In a study conducted by Sadof and Grant in 1997, the Scotch pine trees, *Pinus sylvestris* L., were examined for both resistant and susceptible cultivars in relation to the pine moth herbivore, *Dioryctria zimmermani* (Grote). The findings revealed that monoterpene levels varied considerably when the plants were under attack; notably, limonene was the only compound that consistently showed higher concentrations in the resistant cultivars. Furthermore, Cates and Redak, (1998) reported that the limonene acts as an oviposition deterrent for numerous herbivores and is toxic to various herbivore species. The study conducted by Flamini et al. in 2007 focused on the volatile emissions of different plant organs and pollen from *Citrus limon*, revealing interesting variations in the emission patterns of limonene. The research focused on different developmental stages of the plant, including young and mature leaves, buds, stamens, petals, pollen, and the pericarps of ripe and unripe fruits. Limonene was found to be the primary volatile compound in the gynaecium, epicarp, and young leaves, accounting for around 65% of the emissions in many samples. As the leaves matured, the limonene content decreased to 30.1%, which may be associated with the production of this defensive metabolite in the more vulnerable young leaves.

The buds showed a limonene emission of 38.9%, which rose to 44.3% as the flowers opened, suggesting that these variations could function as orientation cues for pollinators. Comparable findings were documented in the late 1980s when Armbruster et al. (1989) examined the ecological interaction between *Dalechampia magnoliifolia* and *D. spathula* (Euphorbiaceae) in relation to their pollinator, a male Euglossine bee. The morphology of the flowers, the size of the male bee, and the floral fragrances emitted from various parts of the flowers were recognized as significant elements influencing pollination biology. Notably, the flowers, particularly the pollen, were found to be abundant in limonene, which played a crucial role in attracting the pollinator. It is believed that limonene and other monoterpenes play a crucial role as allelopathic agents in hot and dry regions. Their high vapor density allows essential oils to penetrate the soil effectively, which can harm underground organisms, such as the roots of adjacent plants. Scrivanti et al. (2003) assessed the allelopathic properties of limonene and the essential oil from *Tagetes minuta*, which comprises 66.3% limonene, focusing on its impact on the roots of *Zea mays*. Both limonene and the crude essential oil demonstrated an inhibitory effect on the root growth of *Z. mays* seedlings. After a 96-hour exposure period, limonene reduced the root length to 13.56 cm, in contrast to the 15.09 cm observed in the untreated roots. The essential oil derived from *T. minuta* resulted in a further reduction, with root growth measuring only 6.21 cm compared to the untreated roots. It is evident that limonene, as a primary component, along with other monoterpenes present in the essential oil, significantly impacted this activity. This allelopathic characteristic indicates that plants releasing limonene from their root systems may effectively inhibit or completely prevent the growth of neighboring plants.



Nissam Sainudeen *et al.*,**The biological properties of limonene**

Limonene exhibits notable chemopreventive and chemotherapeutic characteristics, as demonstrated by numerous research studies investigating its medicinal capabilities. The widespread application of limonene in beverages, cosmetics, and various flavoring products has sparked interest in its antimicrobial, anticancer, toxicity, antiparasitic, and other beneficial properties.

Aromachological properties

Limonene, a compound found in essential oils, holds significant value and garners considerable interest among consumers due to its distinctive aroma. Consequently, numerous major fragrance companies are actively seeking highly purified limonene derived from the essential oils of specific fruits and flowers. This research focuses on the extraction process of essential oil from lime peel waste. Research conducted by Braddock and Cadwallader (1995) and Mazzaro (2000) has shown that D-limonene is a low-cost byproduct of the orange processing industry, typically costing between U.S. \$1 and \$2 per kilogram. This compound is regarded as an appropriate substrate due to its structural similarity to a variety of important and high-value flavor and medicinal compounds that are highly sought after in the market. The most common derivatives of limonene consist of oxygenated compounds such as alpha-terpeniol, perillyl alcohol, carveol, and carvone. According to Chubukov Victor *et al.* (2015), limonene is the predominant essential oil component in citrus fruit peels, characterized as a colorless liquid aliphatic hydrocarbon from the cyclic monoterpene category. D-limonene is commonly used as a flavoring and aromatic additive in a range of products such as soaps, detergents, cosmetics, pharmaceuticals, and food. Furthermore, it finds broad applications in the manufacturing of resins, acts as a wetting or dispersing agent, and is effective in pest control measures. Carvone, a common terpenoid, is sourced from over 70 different plant species. It comprises two enantiomers: R-(-)-carvone, which is recognized for its spearmint fragrance, and S-(+)-carvone, known for its caraway scent, as highlighted by Chubukov Victor *et al.* (2015).

According to Sarkic and Stappen (2018), carvone is a monoterpene predominantly found in the essential oils of spearmint, caraway, and dill. The R-(-) or L-carvone variant possesses a moderately strong, sweet minty fragrance. Presently, carvone is utilized in various pharmaceutical and cosmetic formulations. Additionally, carvone and other monoterpenes derived from plants are extensively employed in both traditional and contemporary food and beverage applications. Furthermore, carvone plays a crucial role in agriculture, particularly in crop protection and as an anti-sprouting agent for tuber storage. Duetz *et al.* (2003) identified carveol as a natural, monocyclic, unsaturated terpenoid that serves as a crucial constituent of the volatile oils found in spearmint and caraway. This compound exists in two enantiomeric forms: cis-(-)-carveol and trans-(+)-carveol. Characterized as a colorless liquid, carveol exhibits high solubility in oils while remaining insoluble in water. Its aroma and taste closely resemble those of spearmint and caraway oils, making it valuable as a fragrance and flavoring agent in both the cosmetics and food industries. Hassan *et al.* (2019) indicated that Perillyl alcohol, along with its precursors sourced from limonene, belongs to the category of cyclic monoterpenes that are produced via the mevalonate pathway in plants. The primary sources of Perillyl alcohol are the essential oils extracted from various plants, such as sage, lavender, peppermint, and lemongrass. Bailey *et al.* (2003) reported that the Perillic acid belongs to the category of organic compounds referred to as perillate or menthane monoterpenoids. Perillic acid is a water insoluble, hydrophobic and comparatively neutral compound. Perillic acid has a potent antimicrobial and antitumor activity.

CONCLUSION

Limonene, primarily recognized for its use as a fragrance, possesses a diverse range of potential applications as a bulk material. To facilitate the production of biomaterials, solvents, and fuels, a reliable and scalable source of limonene is essential. While microbial production has the potential to fulfill this requirement, it necessitates considerable engineering advancements. Currently, the yields achieved by various microbial systems must be enhanced by at least two orders of magnitude to achieve cost competitiveness with limonene derived from plants.





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This improvement would enable the extensive utilization of microorganisms for the production of limonene in new bulk applications, including solvents and biomaterials.

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Evaluation of Antibacterial Activity and Bioactive Compounds in *Solanum trilobatum* Extracts

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ABSTRACT

Solanum trilobatum, a widely used medicinal herb, is known for its antibacterial properties against various bacterial pathogens. This present study investigates the phytochemical constituents and antibacterial activities of solvent extracts (acetone, methanol, ethanol, and aqueous) from the leaves, roots, and fruits of *Solanum trilobatum*. The bioactive compounds were characterized using Fourier Transform Infrared (FT-IR) spectroscopy and Gas Chromatography-Mass Spectrometry (GC-MS). The plant materials of *Solanum trilobatum* were air-dried and subjected to Cold percolation extraction for 48 hours with intermittent shaking. The *Solanum trilobatum* extracts were filtered using Whatman No. 1 paper. The antibacterial activity was evaluated using the Disc diffusion method against four pathogenic bacteria: *Salmonella typhimurium* (ATCC 14028), *Pseudomonas aeruginosa* (ATCC 27853), *Escherichia coli* (ATCC 8739), and *Staphylococcus aureus* (ATCC 25923). The results revealed that methanol extracts exhibited the highest antibacterial activity among the solvents tested, with significant inhibition zones against all bacterial strains. *Staphylococcus aureus* was the most susceptible, while *Pseudomonas aeruginosa* showed the least susceptibility. GC-MS analysis identified 21 bioactive compounds in the methanol extract of the leaves, indicating its rich phytochemical profile. In conclusion, *Solanum trilobatum* extracts, particularly methanol, demonstrated potent antibacterial properties, suggesting its potential for developing novel antimicrobial agents. This study highlights the therapeutic



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promise of *Solanum trilobatum* in combating bacterial infections and provides a foundation for further pharmacological exploration.

Keywords: *Solanum trilobatum*, Antibacterial activity, Fourier Transform Infrared (FT-IR) spectroscopy and Gas Chromatography-Mass Spectrometry (GC-MS).

INTRODUCTION

The world's growing population depends heavily on medicinal plants for the production of life-saving medications. The World Health Organization (WHO) estimates that up to 80% of people on the planet are primarily reliant on traditional medicinal herbs. Plant materials are the source of many contemporary medications, accounting for around 25% of prescription medications [1]. Additionally, plant sources are the source of the most valuable anti-cancer medications, such as vinblastine, vincristine, and paclitaxel, as well as the widely used painkiller aspirin [2]. In poor nations, where traditional medicine plays a significant role in healthcare, a significant reliance on plants exists [3]. Conventional medication use has unfavourable risks and adverse effects. India possesses a wealth of information regarding the use of plant-based medications for both therapeutic and preventative purposes. The subcontinent of India is ideal for growing a broad variety of aromatic and medicinal plants that may be utilized as raw materials for the agrochemical, pharmaceutical, fragrance, and cosmetic industries due to its diverse soil and climate. Many of these plants are harvested from their natural habitats, mostly for usage in domestic pharmaceutical companies. Several of these plants yield useful medications with significant export potential [4]. The indiscriminate use of commercial antimicrobial medications, which are often utilized in the treatment of infectious diseases, has led to the development of multiple drug resistance against numerous microbial illnesses in the modern world. Apart from this issue, antibiotics can also have negative consequences on the body, such as immunological suppression, hypersensitivity, and allergic responses. Given the rising prevalence of antibiotic resistance in bacteria of medical value and the ongoing demand for novel and potent therapeutic medicines, this circumstance compelled scientists to look for new antimicrobial compounds. Thus, the demand for innovative and potent therapeutic medicines to counteract the negative effects of chemicals remains continual. As a result, several antimicrobial medications derived from medicinal plants are required to treat infectious diseases [5]. *Solanum trilobatum* L. is an uncommon, thorny creeper belonging to the *Solanaceae* family. It is a perennial medicinal herb with bluish violet flowers that grows in some of the warmer portions of tropical and subtropical climates. This ethno-botanical plant, which the local tribes, peasants, and herbalists refer to as "Thuduvilai," is well-known for its special therapeutic qualities [6]. The leaves of *Solanum trilobatum* contain trace amounts of calcium, iron, phosphorus, carbohydrates, fat, and crude fiber. Different plant components have a unique therapeutic quality that has great promise. The plant's leaves and stems are prepared for use in herbal medicine to treat a variety of conditions, including leprosy, asthma, difficult parturition, halt blood vomiting, lower blood sugar, and bilious matter phlegmatic rheumatism. It was also discovered to possess antitumor, antioxidant, antifungal, and antibacterial qualities [7, 8]. The present research is aimed to identify the active ingredients in the extracts and assess the antibacterial activity of the medicinal plant *Solanum trilobatum*.

MATERIALS AND METHODS

Collection of Pathogenic Bacteria

The bacteria selected for the present research was collected from the American Type Culture Collection (ATCC) for an Antibacterial investigation. The pathogenic bacteria obtained are *Staphylococcus aureus* (ATCC25923), *Pseudomonas aeruginosa* (ATCC 27853), *Escherichia coli* (ATCC 8739) and *Salmonella typhimurium* (ATCC 14028). The collected bacterial isolates were maintained on Nutrient agar slants and stored at 4°C in a Refrigerator.



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Adequate *Solanum trilobatum* L. plant material was gathered in and around the Cuddalore region of Tamil Nadu, India. Specimens were shaken off and quickly rinsed with tap water to remove any remaining soil or dust from the field. Plants were moved into the lab and put in paper bags. Leaves, roots, and fruits were among the healthy plant materials that were carefully cleaned with tap water and then shade-dried for a period of two weeks at room temperature. Subsequently, the fruits, roots, and leaves were ground into a powder using an Electric blender. Each powder was then separated from the plant fibers using a 315 mm-sized nylon screen. At last, the powders were gathered and kept apart in bottles with screw caps so they could be used later.

Preparation of Plant Extract**Solvent Extraction**

The antibacterial activity of fresh leaves, roots and fruits was assessed in the current investigation. The Cold percolation process was used to create plant extracts. For ten days, the fruits, roots, and leaves were allowed to air dry at room temperature. Weighing and powdering the completely dried plant materials was done. For 48 hours, the powdered leaves, roots, and fruits (5 gm each) were shaken intermittently at 300 rpm while soaking in 50 ml of various solvents, including acetone, methanol, ethanol, and aqueous. Subsequently, Whatman No. 1 (110mm) filter paper was used to filter the plant extracts, and the resulting filtrate was collected in separate clean beaker.

In vitro Antibacterial Assay

The Disc diffusion method was used to assess the Antibacterial activity of extracts from fruits, roots, and leaves. The Mueller Hinton agar was prepared and swabbed with sterilized cotton swabs that had been dipped in broth containing the Test bacterial cultures. The concentrations of the plant extract to be tested (50µg/ml, 100µg/ml, 150µg/ml, and 200µg/ml) were produced and then separately dipped in sterile discs. To guarantee that the sterile impregnated discs containing plant extracts made full contact with the agar surface, they were carefully put on the surface using sterile forceps. A 500 mg control disc of Meropenem was placed on the top of the Mueller Hinton agar. After that, each plate was incubated for 24 hours at 37 °C with the lid on, and the diameter of the zone of inhibition was measured and reported in millimeters [9].

Fourier Transmission Infrared (FTIR) Spectroscopic Analysis on Leaves of *Solanum trilobatum* L.**Analysis of active principle compounds in the *Solanum trilobatum***

The active principle of *Solanum trilobatum* L. was qualitatively analyzed using the Fourier Transmission Infrared (FTIR) technique [10].

Preparation of Potassium Bromide (KBr) discs

Thermo Nicolet, AVATAR 330 FT-IR system, Madison, WI 53711-4495 was used to record the FT-IR spectra (Thanjavur, Indian Institute of Food Processing Technology). A pure Potassium bromide salt was used to grind the sample of air-dried leaves in order to eliminate the scattering impact of the big crystals. After that, the powdered combination is compressed in a mechanical press to create a transparent pellet that the spectrometer's beam may pass through.

Infrared analysis

The analysis spectrum's frequency ranged from 4000 to 500 cm wave number, and the vibration spectrum was captured as a graphical representation. Bruker, a German company, manufactured the FTIR analysis equipment.

Determination of Phytochemical Contents using Gas Chromatography - Mass Spectrum (GC-MS) Analysis**Sample Collection and Processing**

A homogeneous powder was created by grinding fresh *Solanum trilobatum* leaves, which were subsequently dried at room temperature. For future usage, store in an airtight container. Using 50 milliliters of methanol and continuous shaking for 24 hours at room temperature, five grammes of powdered leaves were extracted. With the use of a



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suction pump, the mixture was then twice filtered using Whatman No. 1 filter paper. The solvent was then gathered and put into bottles with screw caps.

Gas Chromatography- Mass Spectrum conditions

1. Capillary column 30m × 0.25 mm coated with 0.25 μ M film of HP-5.
2. Sample elution using 50: 1 helium was used as carrier gas at 1.0 ml min⁻¹.
3. Column temperature 100°C for 1 minutes increased 10°C min⁻¹ to 275°C min⁻¹ for 20 minutes.
4. Time taken for chromatography per sample in 40 mins.

Analysis of the Phytocomponents in *Solanum trilobatum* leaves using GC-MS technique

The filtrate was put into the GC-Column in a microliter volume. Subsequently, the material evaporates and is transported away by the helium carrier gas, causing it to be separated into distinct fractions. The mass spectra of every component was recorded when the sample fraction exiting the column was introduced into the mass detector. The unknown component's mass spectrum was compared to the known spectrum through the use of database dictionaries that were accessible at Annamalai University's central library.

Identification of Components

The National Institute of Standards and Technology (NIST) database was utilized to interpret the GC-MS results. The components kept in the NIST collection were compared to the spectrums of the unknown components. The compounds were then identified based on their structure, molecular weight, and molecular formula.

RESULTS

The outcome demonstrated that *Solanum trilobatum* extracts from its leaves, roots, and fruits had a noticeable antibacterial impact on *Staphylococcus aureus*. The outcome was shown in the Table-1. For acetone extract, the highest zone of inhibition is 13 mm in 200 μ l. For the methanol extract, the potential zone of inhibition is found at 200 μ l at a distance of 14 mm. The fruit extracts significantly reduced the growth of *Staphylococcus aureus*. In 200 μ l of acetone extract, the maximal zone of inhibition is found at 14 mm, while in 200 μ l of methanol extract, it was 13 mm. The extracts of *Solanum trilobatum* leaves, roots, and fruits demonstrate antibacterial activity against *Pseudomonas aeruginosa* (Table - 2). A considerable inhibition of 18 mm was noted in 200 μ l for the leaf methanol extract. The highest level of inhibition of the root extracts was measured in 200 μ l of ethanol extract (16 mm), and in 200 μ l of methanol extracts (14 mm). A promising inhibition of 12 mm was obtained in 200 μ l for fruit methanol extracts. The outcome demonstrated that *Solanum trilobatum* extracts from the leaves, roots, and fruits also have antibacterial activity against *Salmonella typhimurium*. The Table - 3 showed that the acetone extract of fruits displayed antibacterial activity (11 mm) in 200 μ l, but the ethanol extract of roots and the leaf extract shown antibacterial activity (12 mm and 11 mm, respectively) in 200 μ l. The outcome demonstrated that *Solanum trilobatum* extracts from its leaves, roots, and fruits had a noticeable antibacterial impact on *Escherichia coli*. For methanol extract, the greatest zone of inhibition (12 mm) is found in 200 μ l. In 200 μ l of ethanol extract, a moderate inhibition of the root extract (14 mm) was seen. Fruits were extracted with acetone, and the findings showed antibacterial activity (14 mm) in 200 μ l (Table - 4). The zone of inhibition for *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Salmonella typhimurium*, and *Escherichia coli* was 10 mm, 11 mm, 11 mm, and 10 mm for Meropenem, the positive control (Table - 5). In the current research work, the FTIR spectroscopic examination of the *Solanum trilobatum* Leaves sample revealed several peaks in the functional group area between 4000-650 cm⁻¹ (Figure - 1). However, the *Solanum trilobatum* methanol extract's Gas Chromatography Mass Spectrums (GC-MS) analysis revealed that the leaf sample included 21 distinct chemicals (Table – 6 and Figure - 2).





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DISCUSSION

The emergence of microbial resistance and the prevalence of lethal opportunistic infections linked to AIDS, antineoplastic treatment, and transplants have made the quest for novel, effective antimicrobial medicines vital. Numerous antimicrobial agents have been identified via the use of ethnobotanical data, and many of these compounds have been extracted from therapeutic plants. The secondary metabolites found in plants are usually responsible for the positive therapeutic effects of plant materials. However, a mixture of the metabolites is typically responsible for its attribution rather than a single component. The idea that the mix of secondary products in a certain plant is taxonomically distinct is compatible with the fact that the therapeutic properties of plants are exclusive to a given plant species or group [11]. When selecting a plant for pharmacological investigation, a number of ethnobotanical approaches are typically used in the screening process. The search for novel antimicrobial agents has become necessary due to resistance to currently existing antibiotics [12]. Herbs and medicinal plants are favored sources of active molecules that are used as lead compounds in the production of a range of pharmaceutical products [13]. The *in vitro* antibacterial activity of *Solanum trilobatum* in this investigation demonstrated its inhibitory effect on the examined microorganisms. Significant inhibition of the bacteria was seen in all plant extracts. When the extracts were compared, the antibacterial activity of the leaf extracts was higher than that of the fruit and root extracts. When compared to other plant extracts, *Solanum trilobatum* fruit extracts were generally shown to have lower antibacterial activity. Methanol extracts of *Solanum trilobatum*, namely the leaves, roots, and fruits, had the most antibacterial activity when compared to acetone, ethanol, and aqueous extracts.

It was discovered that the solvent extracts had more antibacterial activity than the aqueous extracts. The solvent's superior polarity in dissolving both polar and non-polar plant components from *Solanum trilobatum* might be the cause. However, in contrast to the current investigation, Gopalakrishnan *et al.* [14] reported that while the *Solanum trilobatum* aqueous extract showed the greatest inhibitory efficacy against *Klebsiella pneumoniae*, *Staphylococcus aureus* was only modestly inhibited by the extract as a whole. The least amount of inhibitory action against *Escherichia coli* and *Pseudomonas aeruginosa* was displayed by aqueous, methanol, and ethanol extracts. Additionally, Hema and Sathya Savithri [15] assessed the antibacterial properties of *Solanum trilobatum* methanolic extract against *Escherichia coli* and *Bacillus cereus*. According to the research, *Solanum trilobatum* leaf extract had the highest activity against *Bacillus cereus*, with a measured zone of inhibition of 12 mm, and, with a measured zone of inhibition of 14 mm. The antibacterial potential of ethanol, acetone, and ethyl acetate extracts of *Solanum trilobatum* leaves, fruits, and flowers was reported by Kannabiran *et al.* [16] and Mihira *et al.* [17]. In line with previous findings, all plant extracts demonstrated antibacterial activity against both Gram-positive and Gram-negative organisms, even though *Pseudomonas aeruginosa* was found to be more susceptible than other test pathogens, such as *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella typhimurium* [18, 19, 20]. However, *Solanum trilobatum*-mediated selenium nanoparticles demonstrated strong suppression against *Lactobacillus* sp., *Candida albicans*, and *Streptococcus* variants, according to Sarojini *et al.* [21] research.

Additionally, *Solanum trilobatum* was reported by Madhumitha *et al.* [22] to possess potent pharmacological effects, including antibacterial, antidiabetic, mosquito larvicidal, antioxidant, and anti-inflammatory qualities. The numerous peaks found in the functional group region of the *Solanum trilobatum* leaves sample underwent FTIR spectroscopic analysis in the current study, with the samples falling between 4000-650 cm⁻¹. The tuber and seed materials revealed that the peaks are involved in intermolecular hydrogen bonding N-H bond either primary, secondary, or tertiary amines, carbonyl group (>C=O), which may be either with the form of carbonyl acid or carbonyl group coupled with -C=C- group. These molecular stretches of active principles tested through FTIR spectroscopical analysis. A few peaks also correspond to the O-H group of alcohols. *Solanum trilobatum* Plant was examined using FTIR analysis, which was based on the skeletal shape of molecular stretches of active principles with aliphatic aldehyde, alkene, and ether groups [23]. The *Solanum trilobatum* Gas Chromatography Mass Spectrum (GC-MS) investigations showed that the leaf sample included 21 distinct chemicals. GC-MS study of *Gloriosa superba* seeds and tubers. Analysis was done on the colchicines, pentadecanoic acid, and hexadecanoic acid [24]. Gas Chromatography Mass Spectrometry (GC-





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MS) investigation of bioactive chemicals found in ethanolic extract of *Solanum torvum* leaves was published by AzaguMadhavan[25]. According to the current investigation, the majority of the test pathogens are inhibited by the acetone, methanol, ethanol, and aqueous extracts. It is possible that some active ingredients in the extracts are what prevent these organisms from growing *in vitro*. The growth of the bacterial organisms may have been inhibited by these active principles acting alone or in combination. Tamil Nadu residents have long used these plants therapeutic properties to treat a wide range of illnesses, including infectious ones. Antimicrobial medicine use in the future is still unknown due to the rising problem of microorganism resistance. As a result, steps must be done to further research into the genetic causes of resistance and to carry out ongoing investigations aimed at creating novel medications, particularly those derived from synthetic or natural medicinal plants. The ultimate objective is to provide the patient with effective and suitable antibacterial medications. Overall, the current study found that *Solanum trilobatum* has made it possible to use plant extracts, which has produced scientific proof for the creation of antibacterial goods and the future treatment of bacterial illnesses.

CONCLUSIONS

The current study's findings unequivocally demonstrated the significance of *Solanum trilobatum* action against pathogenic bacteria that cause infectious diseases. The biologically active ingredients of the medicinal plant *Solanum trilobatum* have been shown to have an advantage in inhibiting pathogenic microorganisms in this note's early examination. Since the local people have long utilized *Solanum trilobatum* to treat certain ailments, further research is necessary to determine the plant's potential for usage in conjunction with other herbal remedies.

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Table – 1: Antibacterial activity of plant extract of *Solanum trilobatum* against *Staphylococcus aureus*

Plant	Extract	Solvents used	Area of Inhibition zone (mm in dm)			
			50µg	100 µg	150 µg	200 µg
<i>Solanum trilobatum</i>	Leaves	Acetone	9	10	11	13
		Ethanol	-	-	10	10
		Methanol	10	11	10	10
		Aqueous	-	12	-	-
	Roots	Acetone	10	10	11	12
		Ethanol	-	-	10	10
		Methanol	11	11	12	14
		Aqueous	-	10	12	12
	Fruits	Acetone	-	-	11	14
		Ethanol	-	-	-	10
		Methanol	11	10	10	13
		Aqueous	-	-	-	12





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Table – 2: Antibacterial activity of plant extract of *Solanum trilobatum* against *Pseudomonas aeruginosa*

Plant	Extract	Solvents used	Area of Inhibition zone (mm in dm)			
			50µg	100 µg	150 µg	200 µg
<i>Solanum trilobatum</i>	Leaves	Acetone	-	11	11	12
		Ethanol	10	10	10	10
		Methanol	10	11	14	18
		Aqueous	-	10	-	11
	Roots	Acetone	-	10	10	11
		Ethanol	11	13	14	16
		Methanol	-	10	13	14
		Aqueous	-	-	10	10
	Fruits	Acetone	-	11	11	11
		Ethanol	-	11	11	12
		Methanol	-	10	11	12
		Aqueous	-	10	10	11

Table – 3: Antibacterial activity of plant extract of *Solanum trilobatum* against *Salmonella typhimurium*

Plant	Extract	Solvents used	Area of Inhibition zone (mm in dm)			
			50µg	100 µg	150 µg	200 µg
<i>Solanum trilobatum</i>	Leaves	Acetone	-	10	10	12
		Ethanol	-	-	10	10
		Methanol	-	-	10	10
		Aqueous	-	-	-	11
	Roots	Acetone	-	10	10	11
		Ethanol	-	-	10	11
		Methanol	-	-	10	10
		Aqueous	-	-	-	10
	Fruits	Acetone	-	-	10	11
		Ethanol	-	-	10	10
		Methanol	-	-	10	10
		Aqueous	-	-	-	10

Table – 4: Antibacterial activity of plant extract of *Solanum trilobatum* against *Escherichia coli*

Plant	Extract	Solvents used	Area of Inhibition zone (mm in dm)			
			50µg	100 µg	150 µg	200 µg
<i>Solanum trilobatum</i>	Leaves	Acetone	10	10	10	10
		Ethanol	-	10	10	10
		Methanol	10	11	11	12
		Aqueous	-	-	-	-
	Roots	Acetone	-	10	10	10
		Ethanol	-	10	10	14
		Methanol	-	-	-	10
		Aqueous	-	-	-	10
	Fruits	Acetone	-	10	10	14
		Ethanol	-	-	11	11
		Methanol	-	-	-	-
		Aqueous	-	-	-	10





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Table – 5: Antibacterial activity of Plant extract of *Solanum trilobatum*

Plant	Solvents used	Area of Inhibition zone (mm in dm) at 100 µg			
		<i>Staphylococcus aureus</i>	<i>Pseudomonas aeruginosa</i>	<i>Salmonella typhimurium</i>	<i>Escherichia coli</i>
<i>Solanum trilobatum</i>	Acetone	-	-	-	-
	Ethanol	-	-	-	-
	Methanol	-	-	-	-
	Meropenem	10	11	11	10

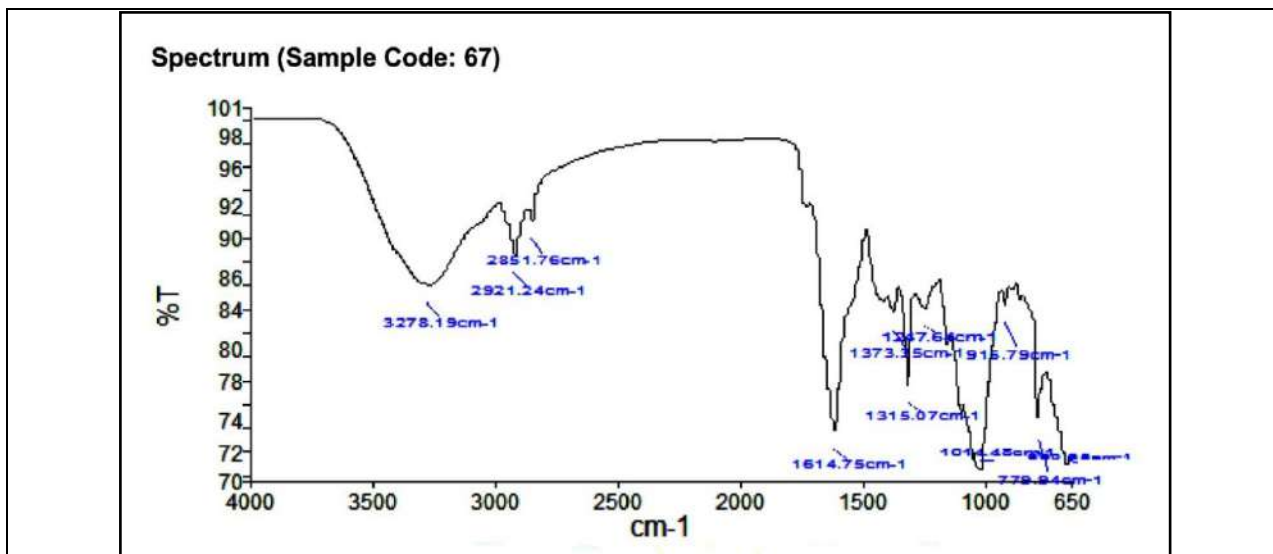
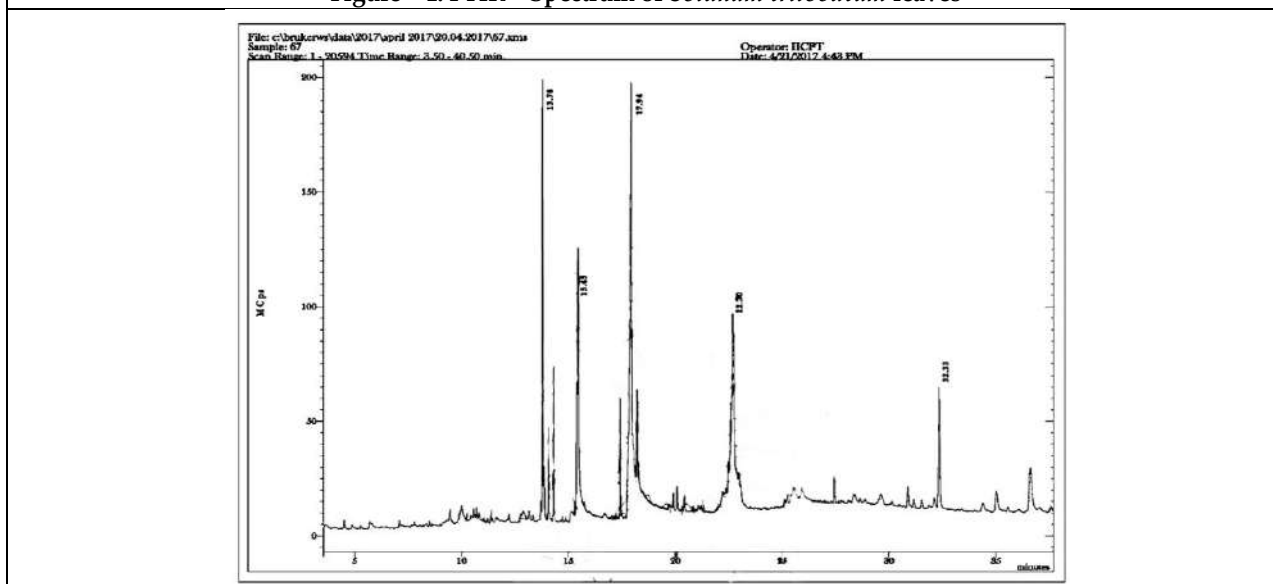
Table - 6: Bioactive compounds present in Leaves of *Solanum trilobatum* by GC-MS

S.No	Retention Time	Name of the compounds	Molecular formula	Molecular weight	Peak Area (%)
1	4.51	4H-Pyran-4-one,2,3-dihydro-3,5-dihydroxy-6-methyl-	C ₆ H ₈ O ₄	144	0.22
2	9.46	Phenol,2-(1,1-dimethyl-2-propenyl)-3,6-dimethyl-	C ₁₃ H ₁₈ O	190	0.28
3	10.01	Dodecanoic acid, 3-hydroxy-	C ₁₂ H ₂₄ O ₃	216	0.86
4	10.71	Fumeric acid, ethyl 2-(2-methylenecyclopropyl) propylester	C ₁₃ H ₁₈ O ₄	238	0.33
5	11.38	Acetic acid, (1,2,3,4,5,6,7,8-octahydro-3,8,8-trimethylnaphth-2-yl) methyl ester	C ₁₆ H ₂₆ O ₂	250	0.36
6	12.22	α-Santonin	C ₁₅ H ₁₈ O ₃	246	0.27
7	13.15	2-Bromotetradecanoic acid	C ₁₄ H ₂₇ BrO ₂	306	0.22
8	13.78	3-hexadecyne	C ₁₆ H ₃₀	222	8.95
9	13.84	n-Heptadecanol-1	C ₁₇ H ₃₆ O	256	1.23
10	14.07	7-Octadecyne,2-methyl-	C ₁₉ H ₃₆	264	1.73
11	14.30	3-Octadecyne	C ₁₈ H ₃₄	250	3.00
12	15.45	n-Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	12.41
13	17.41	Phytol	C ₂₀ H ₄₀ O	296	2.95
14	17.94	9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)-	C ₁₉ H ₃₂ O ₂	292	26.00
15	18.21	Octadecanoic acid	C ₁₈ H ₃₆ O ₂	284	7.49
16	22.70	α-Amyrin	C ₃₀ H ₅₀ O	426	22.91
17	27.44	Squalene	C ₃₀ H ₅₀	410	0.66
18	30.87	γ-Tocopherol	C ₂₈ H ₄₈ O ₂	416	0.77
19	32.33	dl-α- Tocopherol	C ₂₉ H ₅₀ O ₂	430	4.88
20	34.99	Stigmasterol	C ₂₉ H ₄₈ O	412	1.00
21	36.60	β-Sitosterol	C ₂₉ H ₅₀ O	414	3.48





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Figure - 1: FTIR – Spectrum of *Solanum trilobatum* leavesFigure - 2: Bioactive compounds present in Leaves of *Solanum trilobatum* by GC-MS Analysis



RESEARCH ARTICLE

Phytochemical Screening and Evaluation of Anti-Proliferative Effects of *Mukia maderaspatana* in MCF7 Cell Lines

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ABSTRACT

Mukia Maderaspatana L. is an important medicinal plant used as an herbal drug for cough and cold and is well integrated into South Indian food. The present study evaluated the phytochemical constituents, antimicrobial, antioxidant, and hepatoprotective properties of *Mukia Maderaspatana*. Qualitative analysis of the aqueous and ethanolic extracts revealed the presence of bioactive compounds such as saponins, flavonoids, alkaloids, and phenols, with ethanolic extract showing a higher concentration of phytochemicals. The antimicrobial activity was evaluated against five bacterial strains using the well diffusion method, where *Bacillus* exhibited the highest inhibition zone. The antioxidant activity of both extracts was measured using DPPH assays, indicating strong free radical scavenging abilities. GC-MS analysis identified the key compounds responsible for the plant's bioactivity. Auto dock simulations further revealed binding affinities of these compounds with liver cancer target proteins, suggesting potential anti-proliferative activity. The results support the traditional use of *M. maderaspatana* in treating various ailments, particularly liver-related diseases.

Keywords: *Mukia maderaspatana*, phytochemical screening, antimicrobial activity, antioxidant activity, anti-proliferative activity, GC-MS analysis.





INTRODUCTION

India possesses one of the world's most sophisticated indigenous medical systems, with a rich heritage dating back more than four millennia (Sazada Siddiqui et al., 2009). Despite the advances in modern medicine, communities in rural and remote areas continue to rely heavily on traditional medicinal practices. This reliance is often due to the high cost and limited availability of synthetic medicines, which may also be associated with contamination and side effects (Pandey et al.). Even in urban areas, many people still use medicinal plants to treat common ailments such as colds, coughs, fever, headaches, snake bites, skin conditions, and dental infections. *Mukia maderasapatana* (Linn.) also known as *Melothria maderasapatana* or *Cucumis maderasapatana*, is a member of the Cucurbitaceae family. This climbing or prostrate herb is widespread throughout India, growing in both wild and cultivated kitchen gardens. Traditionally used as a leafy vegetable in South India, the plant has been employed in treating a variety of ailments, including cough, cold, constipation, vertigo, burning sensations, dyspepsia, flatulence, and dental pain (Boobalan Raja et al., 2010). While the ethno-medicinal importance of *Mukia maderasapatana* is well-documented, there are few scientific studies available on its nutrient composition. Previous research has focused primarily on the antimicrobial properties of its aerial parts using different solvents such as chloroform, ethanol, hexane, ethyl acetate, and methanol. Given this gap, the present study seeks to explore the phytochemical profile of the plant in aqueous and ethanolic leaf extracts. Additionally, the study aims to evaluate its antibacterial activity against various bacterial strains, along with its antioxidant potential and hepatoprotective activity.

MATERIALS AND METHODS

Collection of plants

Mukia maderasapatana (Linn.) was obtained from its natural habitat in the Tiruchirappalli region, Tamil Nadu, India in December 2017. They were shade-dried, powdered, sieved, and stored prior to further use.

Extraction

20 g of the dried rhizome derived from the plant *Mukia Maderasapatana* was ground and changed into a coarse powder. The powder was put in a Soxhlet extractor harboring 500 mL of methanol and kept for 8 hours. This procedure was repeated three times. The extracts were concentrated within a rotary evaporator for 75 min (vacuum condition, 60°C) and then stored at 4 °C. The extracts of *Mukia Maderasapatana* were dissolved in Dimethyl sulphoxide (DMSO) for preparations of different concentrations and were tested for cytotoxicity.

Phytochemical analysis

The crude powdered plant samples were taken for preliminary phytochemical screening to identify the presence of secondary metabolites (alkaloids, flavonoids, saponins, tannins, carbohydrates, amino acids, steroids, glycosides, terpenoids) using standard established methods (Harbone, 1973).

Antimicrobial Activity Disc Diffusion Method:

In vitro antimicrobial was carried out by disc diffusion technique in whatman no;1 filter paper disc with 4mm diameter was impregnated with a known amount test samples of the disc were loaded each with 10µl of the extract by the first applying 5µl with the pipette allowed to evaporate than applying another 5µl than drying again. The positive control contained a standard antibiotic disc sterile disc used as a negative control. The impregnated disc along with the control (streptomycin) was kept at the center of agar plates, and seeded with test bacterial cultures. The discs were then placed individually using sterile forceps in appropriate grids which were marked on the undersurface of the plates Petri plates and kept for incubation at room temperature for 24 hours. After incubation plates were observed for zones of inhibition and recorded in millimeters.





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Determination of Antioxidant Activity Using DPPH

The ability of *Mukia maderasapata* to scavenge 1, 1- diphenyl-2 picrylhydrazyl (DPPH) was measured by the reported method (Alothman et al., 2009). A mixture of absolute methanol and extract served as blank. Ascorbic acid was used as standard and different concentrations of the extract (50,100,150,200 and 250 µl) were marked as tests. Finally, the DPPH reagent was added to all the test tubes including blank. Then, the absorbance of all samples was read at 515nm.

Calculation

% Antioxidant activity = {(absorbance at blank) – (absorbance at test) / (absorbance at blank)} X 100.

MTT Assay

The anticancer activity of samples on MCF-7 was determined by the MTT assay (Mosmann, 1983). Cells (1×10^5 /well) were plated in 1ml of medium/well in 24-well plates (Costar Corning, Rochester, NY). After 48 hr incubation, the cells reached the confluence. Then, the cells were incubated in the presence of various concentrations of the samples in 0.1% DMSO for 48h at 37°C. After removal of the sample solution and washing with phosphate-buffered saline (pH 7.4), 200µl/well (5mg/ml) of 0.5% 3-(4, 5-dimethyl-2-thiazolyl)-2, 5-diphenyl--tetrazolium bromide cells (MTT) solution was added. After 4h incubation, 0.04M HCl/ isopropanol was added. Viable cells were determined by the absorbance at 570 nm. Measurements were performed and the concentration required for a 50% inhibition of viability (IC₅₀) was determined. The absorbance at 570 nm was measured with a UV- Spectrophotometer using wells with untreated cells as blanks. The effect of the samples on the proliferation of MCF-7 was expressed as the % cell viability, using the following formula:

% cell viability = OD value of treated cells / OD value of control cells × 100.

RESULT AND DISCUSSION

Phytochemical screening was conducted on various extracts of *Mukia Maderasapata* as a preliminary assessment. The ethanolic extract exhibited the highest diversity of phytochemicals, including carbohydrates, proteins, alkaloids, tannins, saponins, steroids, and glycosides, followed by the acetone extract. Additionally, the aqueous extract from both the stem and leaf showed the presence of flavonoids. However, alkaloids, saponins, phenols, and flavonoids were absent in the hexane and ethyl acetate fractions, though steroids and glycosides were identified in these extracts. Notably, the aqueous extracts from both the leaf and stem contained alkaloids and flavonoids. These findings suggest that the leaves of *M. maderasapata* contain significant amounts of tannins, alkaloids, and flavonoids compared to the stems. These phytoconstituents may serve as sources of pharmacologically active agents and natural antioxidants. The observed beneficial activities of *M. maderasapata* in traditional practices may be attributed to the presence of these phytochemicals, as demonstrated in various studies. For instance, flavonoids are known for their antibacterial, anti-inflammatory, anti-allergic, and antiviral properties (Alan and Miller, 1996). Many of these effects are linked to their roles as potent antioxidants, free radical scavengers, and metal chelators. Steroidal compounds are significant in pharmacology due to their association with sex hormones. Additionally, saponins have been reported to exhibit hypocholesterolemia and tumor-inhibiting activities in experimental models (Johns, 1996) and may enhance nutrient absorption during digestion. Alkaloids often possess pharmacological effects and are utilized in both medicinal and recreational contexts (Roger and Wink, 1998). Tannins and phenols, which together comprise the polyphenolic group, are recognized for their antioxidant, anticancer, and antimicrobial properties (Rice et al., 1996). The presence of tannins in *M. maderasapata* suggests potential applications in various industries, including food, pharmaceuticals, and leather (Nguji, 1988). Furthermore, glycosides have been reported to influence insulin secretion in vitro (Sumana and Suryawashi SA, 2001).

Antibacterial activity using well diffusion method

Notably, the inhibition zones for *Bacillus* varied with different concentrations of the extracts, suggesting a dose-dependent antibacterial effect. This variability highlights the strong antibacterial properties of the leaf extracts,



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reinforcing the potential of *M. maderaspatana* as a source of natural antimicrobial agents. Among the different extracts tested, the ethanolic extract displayed the highest efficacy against all tested bacterial strains (*Bacillus* sp, *Pseudomonas aeruginosa*, *E. coli*, *Klebsiella*, and *Staphylococcus aureus*.) indicating its superior antibacterial activity. The findings of this study suggest that the ethanolic extracts of *M. Maderasapatana* possess a high phenolic content, which is likely responsible for their potent antibacterial properties. In aqueous extracts, the polarity of the solvent seems to play an important role in exhibiting potential antibacterial activity. The differential activity might be due to the presence of some oils, wax, rennin, or fatty acids in the plant material which may block the plant extract from entering the bacterial cell wall (Parekh et al., 2006). The results of the present study indicate that acetone and ethanol extract of *M. Maderasapatana* leaf and stem are high in phenolic content and so exhibit strong antibacterial activity. In addition, such results justify the traditional use of *M.maderasapatana* in various diseases. Furthermore, these results support the traditional use of *M. maderasapatana* in various medicinal applications, particularly in treating bacterial infections. The evidence provided herein underscores the need for further exploration of this plant's therapeutic potential, paving the way for its application in modern medicine.

GC-MS Analysis

GC-MS is a combined analytical technique used to determine and identify compounds present in a leaf sample of *Mukia maderasapatana*. The active principles with their retention time (RT), molecular formula, molecular weight (MW) and concentration (%) are presented in Table 6&7. five compounds were identified in ethanolic extract by GC-MS. The major components present in leaf of *Mukia maderasapatana* were[(2,3-Hexanediol, 3,4-dihydro-4-(1,3-Dioxolan-2-yl-dimethoxy-1(2h)-benzopyron-2-one, 4-(benzoylmethyl)-6-methyl-2h-1,4-benzoxazin-3-one, 1-(3,4-ditrimethylsiloxyphenyl)-2-Isopropylaminoethanol, 4A-methyl-1,2,3,4A,5,6,7,octahydro-2-naphthalenol, 2,3-hexanediol, 2,3,4,4-Tetrapropyl-1-(trimethylsilyl)-1-(trimethylsilyloxy)-1,3-diaza-2,4-diborobutane.))]. Seven compounds were identified in aqueous extract 1-(3,4-Ditrimethylsiloxyphenyl)-2-Isopropylaminoethanol, 2,3,4,4A-Tetrapropyl-1-(trimethylsilyl)-1-(trimethylsilyloxy)-1,3-diaza-2,4-diborobutane, Di-tert-butylester of phthalic acid, (ss)-or(RR)-2,3-hexanediol, 3,4-dihydro-4-(1,3-dioxolan-2-yl)-5,7-diamethoxy-1(2H)-benzopyran-2-one, 2,3-Bis (trimethylsiloxy)-2,3-Bis (4-methylphenyl)butane, 4-(Benzoylmethyl)-6-methyl-2H-1,4-benzoxazin-3-one. Phytochemical constituents which contribute to the medicinal activity of *mukia maderasapatana*.

Antioxidant activity

The results revealed that *Mukia maderasapatana* showed a significant effect on DPPH. The OD value shows the ethanolic and Aqueous extract were found in 517nm. The plants can be used as antioxidant because oxidative stress by the free radicals. The free radicals are neutralized by phenolic phytoconstituent possessing hydrogen donation in nature. The radical scavenging assays such as DPPH, hydrogen peroxide and hydroxyl radical proved the antioxidant activity by the *Mukia maderasapata*. (Wickramaratne MN et al 2016)

Anti proliferative activity by MTT assay

Anti-proliferative activity of ethanolic extract in *M.maderspatana* MCF-7 cells was determined by MTT assay as shown in (Table 7; Graph 1, Fig:5). Methanolic extract of *M.maderspatana* exhibited a suppressive effect on cell proliferation in dose dose-dependent manner. Cell proliferation was significantly ($p \leq 0.001$) decreased by viabilities of the rest of the treated groups. The IC₅₀ values were determined based on viability rates of cells that were treated with varying concentrations of the drug for 48h. The results obtained were in concordance with the anti-proliferative activity of ethanolic extracts of *Mukia madersapatna* against the MCF-7 cells where a 60% inhibition was observed at a concentration of 300 µg/mL.

CONCLUSION

The present study reveals that *Mukia maderaspatana* is an important medicinal plant. The preliminary phytochemical screening shows the presence of alkaloids, flavonoids, coumarin, glycosides, terpenoids, tannin, steroids, saponin, phenol, and anthraquinone in higher concentrations in ethanolic extract comparable to Aqueous



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extract of *Mukia maderaspatana*. In exploring alternative therapies, particularly phytotherapy, both ethanolic and aqueous leaf extracts were prepared using an orbital shaker. Various properties of the extracts were analyzed, including phytochemical composition, anti-proliferative activity by MTT assay, antioxidant capacity through DPPH radical scavenging activity, and antibacterial activity against microorganisms like *Pseudomonas aeruginosa* and *E. coli* using the well diffusion method. Additional analyses GC-MS. indicated that both extracts contained a range of compounds identified through GC-MS. We can conclude that the Leaves of *Mukia maderaspatana* are a good source of antioxidants, which might cure diseases related to oxidative stress. GC-MS analysis detected many bioactive compounds from the ethanolic extract of *Mukia maderaspatana* possessing good pharmacological properties. Therefore, isolating, purifying, and characterizing particular bioactive chemicals from *Mukia maderaspatana* might help researchers better understand their distinct pharmacological active principles.

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Table: 1 Phytochemical Screening of Aqueous and Ethanolic Leaf Extract of Mukia Maderasapatana.

S.NO	PHYTOCHEMICAL ANALYSIS	PRESENCE AND ABSENCE OF CHEMICAL CONSTITUENTS.	
		AQUEOUS	ETHANOLIC
1.	Saponins	Positive	Positive
2.	Tanins	Negative	Positive
3.	Flavonoids	positive	Positive
4.	Alkaloids	Negative	Positive
5.	Phenols	Ppositive	Positive
6.	Coumarian	Negative	Positive
7.	Terpenoids	Positive	Positive
8.	Quinine	Negative	Positive
9.	Steroids	Positive	Positive
10.	Glycosides	Positive	Positive

Table:2 Antibacterial Activity Of Ethanol Extract(10mg/MI)

S.NO	Organism	Antibacterial Inhibition on Ethanol extract			
		150	200	250	300
1.	Pseudomonas aeruginosa	7mm	8mm	9mm	10mm
2.	Bacillus	8mm	9mm	11mm	12mm
3.	E.coli	2mm	4mm	6mm	7mm
4.	Klebsiella	4mm	5mm	8mm	9mm
5.	Staphylococcus aureus	4mm	6mm	9mm	12mm

Table: 3 Antibacterial activity of aqueous extract

S.NO	Organism	Antibacterial Inhibition on Aqueous extract			
		150	200	250	300
1.	Pseudomonas aeruginosa	3	4mm	5mm	6mm
2.	Bacillus	4mm	6mm	7mm	8mm
3.	E.coli	2mm	3mm	4mm	5mm
4.	Klebsiella	2mm	4mm	5mm	7mm
5.	Staphylococcus aureus	3mm	4mm	6mm	7mm

Table:4 GC-MS analysis of Aqueous extract from Mukia maderasapatana.

S.NO	PEAK	AREA%	NAME OF COMPOUND IN AQUEOUS EXTRACT	MOLECULAR FORMULA	RT
1.	1	5.99	1-(3,4-Ditrimethylsiloxphenyl)-2-isopropylaminoethanol	C17H33NO3Si2	10
2.	2	10.43	2,3,4,4-Tetrapropyl-1-(trimethylsilyl)-1-(trimethylsilyloxy)-1,3-diaza-2,4-dibrorabutane	C18H44B2N2OSi2	13.929
3.	3	8.97	Di-tert-butylester of phthalic acid	C15H22O4	34.847
4.	7	6.48	(SS)-or (RR)-2,3-hexanediol	C6H14O2	37.503
5.	5	14.81	3,4-dihydro-4-(1,3-dioxolan-2-yl)-5,7-dimethoxy-1(2H)-benzopyran-2-one	C14H16O6	37.39
6.	12	1.41	2,3-Bis(trimethylsiloxy)-2,3-Bis(4'-methylphenyl)butane	C24H38O2Si2	39.215
7.	15	1.29	4-(Benzoylmethyl)-6-methyl-2H-1,4-benzoxazin-3-one	C17H15NO3	39.61





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Table: 5 GC-MS analysis of ethanolic extract from Mukia maderasapatana.

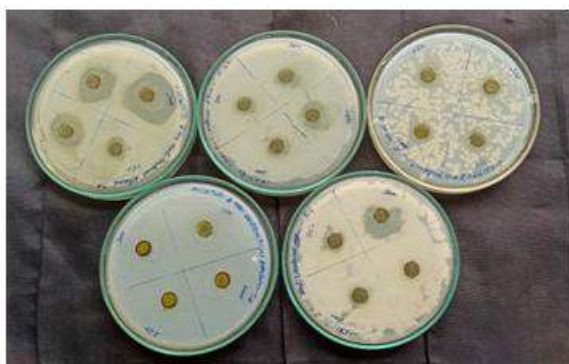
S.NO	PEAK	AREA%	NAME OF COMPOUND IN ETHANOL EXTRACT	MOLECULAR FORMULA	RT
1.	1	9.8	1-(3,4-Ditrimethylsiloxyphenyl)-2-Isopropylaminoethanol	C ₁₇ H ₃₃ NO ₃ Si ₂	10.002
2.	3	15.94	4A-Methyl-1,2,3,4A,5,6,7,octahydro-2-naphthalenol	C ₁₁ H ₁₇ DO	34.859
3.	4	17.59	(SS)-or-(RR)-2,3-Hexanediol	C ₆ H ₁₄ O ₂	37.39
4.	8	11.75	Methyl(3F,4S)-[4-(Benzensulfoxy)-methyl-5-oxotetrahydrofuran-3-yl]Acetate	C ₁₄ H ₁₆ O ₆ S	39.809
5.	2	9.89	2,3,4,4-Tretopropyl-1-(Trimethylsilyl)-1-(trimethylsilyloxy)-1,3-dirza-2,4-diborabutane.	C ₁₈ H ₄₄ B ₂ N ₂ O ₅ Si ₂	13.929

Table: 6 the Antioxidant OD value of the sample at 517 nm

S.NO	SAMPLE	OD VALUE AT 517 nm
1.	Control	-0.0013
2.	Ethanol	1.8057
3.	Aqueous	1.6648

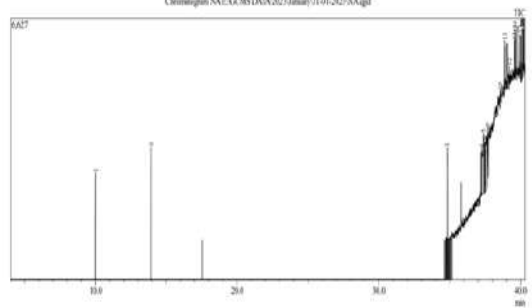
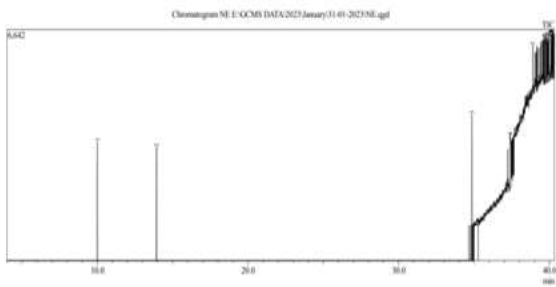
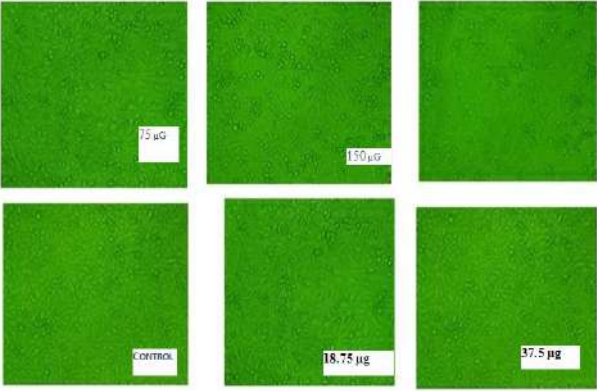
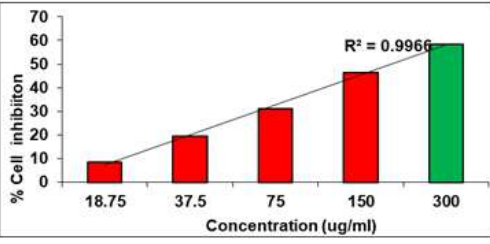
Table:7 Evaluation of Hepatoprotective activity

Conc	18.75 µg	37.5 µg	75 µg	150 µg	300 µg	Cont
ABS	0.065	0.151	0.244	0.367	0.456	0.781
	0.066	0.151	0.245	0.362	0.457	0.785
	0.067	0.152	0.242	0.363	0.457	0.782
Avg	0.066	0.151333	0.243667	0.364	0.45666667	0.782667

**Figure: 1Antibacterial activity of Mukia maderasapatana (ethanol extract)****Figure: 2 Antibacterial activity on Mukia maderasapatana in aqueous**



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Figure: 3 GC-MS analysis of Aqueous extract from Mukia maderasapatana	Figure 4 GC-MS analysis of ethanolic extract from Mukia maderasapatana.
	
Figure: 5 Anti proliferative activity by MTT assay at different concentrations of ethanolic extract from Mukia maderasapatana	
	
Graph 1:Evaluation of Hepatoprotective activity	





Phytochemical and Spectroscopic Characterization of *Millingtonia hortensis* L.f. Flower with Antibacterial Activity Assessment

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ABSTRACT

The present study focuses on the phytochemical screening and bioactive potential of *Millingtonia hortensis* L.f. leaves using four different solvents: petroleum ether, benzene, ethanol and water extracts. Of these, the ethanolic extract exhibited the presence of all tested phytochemical constituents, indicating its richness in bioactive compounds. Advanced analytical techniques, including UV-Vis spectroscopy, FTIR and GC-MS were employed to identify and characterize the functional groups and chemical compounds present in the ethanolic extract. The UV-Vis profile showed different peaks ranging from 200- 900nm with distinct peaks of varying absorption respectively. The FTIR spectrum revealed the existence of substances such as alkene, alkane, alcohol, amide, carboxylic acid, amino and fluoro compounds in the ethanolic flower extract. The GC-MS analysis of ethanolic flower extract yielded several peaks that indicated the presence of 101 phytochemical substances, of which 21 main components were identified. The antibacterial activity of the ethanolic extract was further assessed against three strains of bacteria: *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Streptococcus pneumonia*. The results demonstrated dose-dependent antibacterial efficacy, with higher concentrations showing significant inhibition zones comparable to the standard antibiotic. These findings pave the way for further exploration of its therapeutic applications and the development of plant-based antibacterial agents.

Keywords: Bioactive compounds, antibacterial, UV-Vis, FTIR, GC-MS analysis.



**Parama Sakthi and Gomathy****INTRODUCTION**

In India, traditional medical practices make use of over 7300 plant species. Approximately 90% of the medicinal plants used in daily life are employed as herbal treatments. Man has utilized thousands of native plants to treat and cure illnesses since the beginning of time on every continent. Despite remarkable advancements in the field of allopathy, medicinal plants and their derivatives continue to be a key source of pharmaceuticals in both traditional and modern systems worldwide, with a significant role in therapeutic treatment [1]. The medicinal plants have the potential to be utilized in drug research and synthesis due to the existence of several active ingredients [2]. Now a days, traditional herbal remedies are becoming increasingly popular, both in developing and developed countries worldwide. The demand for Ayurvedic and traditional herbal medications has increased due to its lack of adverse effects and so modern people are increasingly relying on plant-based drugs [3]. *Millingtonia hortensis* L.f. is the only species in the genus *Millingtonia* and a member of the Bignoniaceae family. The English botanist Thomas Millington gave it the name *Millingtonia*, and the word *hortensis* means “grown in gardens”. It is also referred to as Tree Jasmine, Akash Neem, Neem Chameli, and Cork Tree [4]. *Millingtonia hortensis* Linn is a decorative tree that is planted as an avenue tree in parks and gardens. The tree is widely distributed over South Asia, including Thailand, Burma, India, and Southern China. The tree is easily recognized by its fragrant, highly scented blossoms, and it contains a lot of alkaloids, flavonoids, tannins, and essential oil [5]. It can reach a height of 18 to 25 meters. Its brittle timber is susceptible to storm damage. It is distinguished by its straight stem with few branches and corky bark. The tree blossoms at night throughout the winter months, and by dawn, fragrant blossoms blanket the ground [6]. It's a drought-resistant tree. This plant thrives in full sunlight and may grow in a variety of soil conditions, but likes a moist climate. The tree does not bloom in certain locations, such as Chennai. The plant reproduces through seeds and suckers, which are abundant [7]. Different portions of *M. hortensis* have been used for their medicinal qualities in traditional medicine. The leaves have been used as a cholagogue, a general tonic, an antipyretic, and a remedy for sinusitis [8]. According to reports, the stem bark possesses antimicrobial qualities and has been used to treat respiratory conditions [9]. Roots can heal tuberculosis and alleviate asthma. In Thailand, this flower is known as 'peep'. Flowers, particularly the buds, have been used in the treatment of asthma and as a lung tonic [7, 10]. Since *M. hortensis* L.f. contains a variety of phytochemical ingredients, pharmacological activity including antiproliferative, antimutagenic, antibacterial, antifungal, anticonvulsant, and antioxidant properties have been documented. Additionally, the leaves and flowers displayed larvicidal and antiasthmatic properties, respectively [6]. The present study aimed to identify bioactive compounds through spectral analyses, including phytochemical screening, UV-Vis spectroscopy, FTIR and GC-MS, along with antibacterial activity assays against selected bacterial strains. All analyses and antibacterial activity tests were exclusively performed using the ethanolic extract of the flower, with the objective of establishing standards for the standardization and potential therapeutic applications of this crude extract.

Plant Taxonomy

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Magnoliopsida
Order	:	Lamiales
Family	:	Bignoniaceae
Genus	:	<i>Millingtonia</i>
Species	:	<i>hortensis</i>

MATERIALS AND METHODOLOGY**Collection of Plant Material**

The samples of *Millingtonia hortensis* L.f. flowers were collected in and around Thoothukudi district, Tamil Nadu, India (Figure 1). The flowers were then properly cleaned with running tap water to get rid of any remaining dirt and



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soil particles, and they were left to dry for ten days in the shade. The dried plant material is kept at room temperature (28° C) until the extraction procedure starts. Then, a heavy-duty blender was used to pulverize the dried plant material, which was then sealed in airtight glass container for laboratory analysis (Figure 2).

Preparation of Plant Extracts

The dried flower powder was subjected to solvent extraction using solvents of varying polarity: petroleum ether, benzene, ethanol and water. 10g of powder was first steeped in 50ml of petroleum ether in an airtight conical flask for two days. The flask was periodically subjected to shaking on an electric shaker and then it was filtered through Whatman no 1 filter paper and filtrate was collected into sterile air tight glass vials. The aforementioned techniques were replicated using benzene, ethanol and water [15].

Qualitative Phytochemical Analysis

Preliminary phytochemical analysis was performed on *Millingtonia hortensis* L.f. flower extract made with solvents of varying polarity using particular reagents for several classes of phytoconstituents, in accordance with the standard procedure [11,12]. Phytochemical screening was carried out to identify the major phytochemicals such as aromatic acids, phenols, flavonoids, alkaloids, terpenoids, steroids, coumarins, tannins, saponins, quinones, anthraquinones and catechins.

Characterization of Flower Extract**UV-Vis Spectroscopic analysis**

A UV-Visible Spectrophotometer (Jasco V650 Spectrophotometer) with a slit width of 2nm and a 1 cm cell at ambient temperature was used to perform a UV-Vis Spectrophotometric examination on the flower of *M. Hortensis* extracts. For proximate analysis, the extract was analysed under wavelengths ranging from ultraviolet (190nm) to near infrared (900nm). The ethanolic extract was centrifuged at 3000 rpm for 10 minutes in order to filter it through Whatman No. 1 filter paper for the UV-Vis Spectrophotometer analysis. Using the same solvent, the sample is diluted to the ratio of 1: 10 and the values are recorded.

FTIR Spectroscopic analysis

Fourier Transform Infrared (FTIR) was utilized to determine the extract's distinctive functional groups. Using the Thermo Scientific Nicolet is5, the IR spectrum was acquired. It provides details about the composition of a molecule found in the extract. A tiny amount of *Millingtonia hortensis* flower extract was combined with dried potassium bromide (KBr). After the material was well combined in a mortar, it was compressed for two minutes at a pressure of six bars to create KBr disc. The sample was scanned from 4000 to 400 cm⁻¹ and then the peak values of respected functional groups are noted.

GC-MS Analysis

The presence of active constituents and chemical composition of *Millingtonia hortensis* ethanolic extract was characterized by the use of Gas chromatography and Mass spectroscopy (GC-MS). The GC-MS analysis of *M. hortensis* L. extract was performed by using GCMS- 8040NX, GC-2030, AOC- 20i plus liquid auto samples. The column used was SH- Rxi- 5Sic MS of 30m× 0.25mm× 0.25µm size. The initial temperature range was 50°C with a hold time of 2 minutes. The temperature was further increased to 225°C at a rate of 5°C/minute with a hold time of 4 minutes. Finally, the temperature was raised to 310°C at a rate of 5°C/minute with a hold time of 5 minutes. The ion source of mass spectrophotometer was held at 230°C with an interface temperature at 280°C. Mass scan detection was performed in the range of 50mz to 800mz. The interpretation of chemical compound was achieved by using database stored in NIST library (National Institute of Standards and Technology).

Antibacterial Activity by Well Diffusion Method**Bacterial Pathogens**

The microorganisms of Gram-positive strains such as (*Streptococcus pneumonia* and *Staphylococcus aureus*) and Gram-negative strain (*Pseudomonas aeruginosa*) were used for the evaluation of antibacterial activity.



**Parama Sakthi and Gomathy****Reference Drug and Control**

As the standard reference for bacteria, ampicillin was selected. The test chemicals were soluble in solidified agar that had been coated with a solvent to serve as the controls.

Ethanollic Flower Extraction

20ml of ethanol was macerated with 4 grams of powdered leaf material in a 1:5 ratio for 24 hours at 50° C while being shaken at 130 rpm. After that, the extract was filtered through Whatman No. 1 filter paper. The filtrates were concentrated by employing an evaporator to remove the solvents at 40° C under decreased pressure (Figure 3).

Antibacterial Assay

All the three different bacterial strains were cultured on nutrient agar broth and incubated at 37° C for 18- 24 hours. Following that, a sterile swab was inserted into the produced bacterial suspension, evenly distributed throughout the entire surface area of Mueller-Hinton agar plates, and incubated for 15 minutes. The cultured plates were marked with wells (6mm in diameter). The wells were then injected with positive control (Ampicillin) along with ethanolic leaf extract (25, 50 and 100µg). Each plate was evaluated for the zone of inhibition (in mm) after 24 hours of incubation at 37° C.

RESULT AND DISCUSSION**Preliminary Phytochemical Screening**

In the current investigation, phytochemical screening was carried out utilizing solvents of increasing polarity in order of petroleum ether, benzene, ethanol and water in the flower of *Millingtonia hortensis*. Table 1 indicated both the presence and absence of different types of bioactive constituents such as carbohydrates, proteins, lipids, aromatic acids, phenols, flavonoids, alkaloids, terpenoids, steroids, coumarins, tannins, saponins, quinones, anthraquinones and catechins. Carbohydrates, proteins, lipids, aromatic acids, alkaloids, quinones, anthraquinones and catechins have been detected in petroleum ether (40- 60°C) extract whereas phenols, flavonoids, terpenoids, steroids, coumarins, tannins, saponins were not observed. Phenols, flavonoids, steroids, coumarins, quinones have been observed in benzene extract whereas, carbohydrates, proteins, lipids, aromatic acids, alkaloids, terpenoids, tannins, saponins, anthraquinones and catechins were not noted. Carbohydrates, proteins, lipids, phenols, flavonoids, alkaloids, terpenoids, tannins, saponins, anthraquinones were identified in water extract whereas aromatic acids, steroids, coumarins, quinones and catechins were absent in this extract. All the tested active constituents were present in ethanolic extract. Phenols and flavonoids which are considered as most important component were present in three extracts except petroleum ether. These results were mentioned in Table 1. Mahesh Kumar et al. (2014) and Chumbhalel et al. (2016) found similar results when total phenols, flavonoids, terpenoids, glycosides, and protein were present in chloroform and water extracts of *Millingtonia hortensis* [13, 14]. Similar findings reported by Karthiya et al., 2018 in different extracts (ethanol, chloroform, acetone and water) of *Millingtonia hortensis* L. and *Tecoma stans* L. flowers revealed the presence of saponins, glycosides, terpenoids, flavonoids, quinones and carbohydrates[15]. Janaki et al. (2017) conducted a preliminary phytochemical screening of petroleum ether, ethanol, methanol, chloroform, and aqueous extracts of *Millingtonia hortensis* L. leaves. All of the extracts from their investigation demonstrated the presence of flavonoids, alkaloids, cyanins, phenols, and coumarins [16]. A phytochemical examination of *M. hortensis* L. methanolic leaf extract revealed the presence of flavonoids, glycosides, phenolic compounds, alkaloids, terpenoids and saponins (Sivaraj et al., 2019)[17].

UV-VIS Analysis

The UV-Vis analysis was carried out to identify the phytoconstituents present in the ethanolic flower extract of *Millingtonia hortensis* L. f. The qualitative UV-Visprofile of the ethanolic extract of *M. hortensis* flower was taken at the wavelength of 200 to 900 nm. The spectrum exhibited a characteristic bell-shaped profile with a single distinct peak. The maximum absorbance (A_{max}) was observed at 390 nm, with an absorbance value of 0.889314, indicating the presence of a dominant chromophore absorbing in this region. Absorbance readings at different wavelengths (230





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nm, 286 nm, 390 nm, 444 nm, 566 nm, 734 nm, and 900 nm) showed varying values, were significantly lower and did not form distinct peaks, indicating the absence of additional chromophores in substantial concentrations. Table 2 displays the absorbance at these wavelengths and Figure 4 shows the absorption spectrum of *M. hortensis* extract in the wavelength region of 200- 900nm. The absorption peak at 390 nm is characteristic of compounds with strong light absorption in the near-UV region. This wavelength falls within the typical absorption range for flavonoids, phenolics, or other aromatic compounds, which are known for their $\pi \rightarrow \pi^*$ or $n \rightarrow \pi^*$ electronic transitions [18]. Two main absorption bands are frequently seen in flavonoids: Band I (300–400 nm), which is connected to the B-ring cinnamoyl system, and Band II (240–285 nm), which is connected to the A-ring benzoyl system. The prominent peak at 390 nm suggests the potential dominance of flavonoids or similar phenolic compounds in the *M. hortensis* ethanolic flower extract. Similar results have been observed in additional plant extracts with absorbance in the 380–400 nm region, attributable to these groups of phytochemicals [19].

FTIR Analysis

The IR spectral studies of ethanolic flower fractions of *Millingtonia hortensis* L.f. gave the following characteristic absorption peaks as shown in Figure 5 and Table 3 presents the observed wave numbers along with their corresponding stretching or bending vibrations and the functional groups they represent. These assignments were made based on comparisons with standard FTIR reference ranges and previous studies on plant-based compounds. The band at 3132.68 cm^{-1} is due to C-H and O-H stretch of alkene, alcohol and carboxylic acid. The band at 2361.92 cm^{-1} is assigned to the hydroxyl stretch of carboxylic acid. The bending mode of absorbed water is attributed to the band at 1633.44 cm^{-1} since plant extracts are known to have a high affinity for water. The band at 1400.28 cm^{-1} is due to C-H bend associated with alkane. It is tended to be amino and fluoro compounds by the C-N/F stretch at band 1075.43 cm^{-1} and finally the band observed at 669.16 cm^{-1} is associated with C=C bend of alkene [20, 21, 22].

GC-MS Analysis

The investigation revealed a total of 101 compounds from the ethanolic flower extract based on the peaks detected in the chromatogram. Among these, twenty-one compounds (phytochemical constituents) are selected which might represent most abundant constituents in the extract that could contribute the medicinal quality of the plant. The identification of the phytochemical compounds was confirmed based on the peak area, retention time and molecular formula. The active principles with their retention time (RT), molecular formula, molecular weight (MW) and peak area in percentage in the ethanol extract of *M. hortensis* L. flowers are presented in Table 4 and figure 6. The prevailing compounds in ethanol extract were 2- methylcyclohexanol (23.02%), 1'- hydroxy- 4, 3'- dimethylbicyclohexyl- 3,3'- dien- 2- one (21%), Eicosane (8.20%), Heneicosane (7.04%), 2H- Pyran- 2acetic acid, tetrahydro- 4hydroxy-6pentyl- (5.16%), Eicosane (4.63%), n- Hexadecanoic acid (3.56%), beta- sitosterol (3.19%), cyclobutanecarboxylic acid, decyl ester (2.55%), 2- Methoxymethyl-2methylpyridine-1- carboxyaldehyde (2.53%), Tetratetracontane (2.05%), 10E, 12Z octadecadienoic acid (1.91%). Previous studies showed that the GC-MS analysis of *Millingtonia hortensis* L. flower revealed the presence of 35 compounds. For instance, Aspidoseprmidin 17-ol, 1-acety-19,21-epoxy-15, 16-dimethoxy (R.T:27.90); 2-methyltetracosane (R.T:28.24); Alfaxalone (R.T:29.17); cis-13, 16-Docadienoic acid (R.T: 30.86); Olean-12-ene-3, 15, 16, 21, 22, 28-hexol (R.T: 33.14); Stigmasta-5, 22-dien-3-ol, acetate, (3 β) (R.T: 34.20); β -Sitosterol (R.T: 35.72); Stigmasta-5,24(28)-dien-3-ol, (3 β) (R.T:36.10); Betulin (R.T:37.86), were found along with other major components in the ethanol extract [23].

Antibacterial Activity

The antibacterial activity of an ethanolic extract of *Millingtonia hortensis* flowers against pathogens such as Gram-positive strains (*Streptococcus pneumonia* and *Staphylococcus aureus*) and Gram-negative strain (*Pseudomonas aeruginosa*). The diameter of the clear zone in petri plate cultures was used to objectively evaluate the antibacterial potency and sensitivity of crude extracts with varied degrees of concentration and compared to the standard antibiotic ampicillin (Table 5 and Figure 7). The antibacterial activity has increased with increasing concentrations of the extract. At a lower concentration of 20 μL , the extract produced inhibition zones of 5 mm for *Streptococcus* and *Staphylococcus*, but it did not show any activity against *Pseudomonas*. At 40 μL , the inhibition zones increased slightly to 5.5 mm for *Streptococcus*, 6 mm for *Staphylococcus*, and 5 mm for *Pseudomonas*. At the highest concentration of 60



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μL, the extract demonstrated the strongest activity, with zones of 6 mm for *Streptococcus*, 7 mm for *Staphylococcus*, and 6 mm for *Pseudomonas*. When compared to the standard antibiotic Ampicillin (25 μg), which produced inhibition zones of 6 mm, 6 mm, and 8 mm for *Streptococcus*, *Staphylococcus*, and *Pseudomonas* respectively, the extract was less effective at lower concentrations. However, at 60 μL, its activity against *Streptococcus* and *Pseudomonas* matched that of Ampicillin, and it was slightly more effective against *Staphylococcus*. These results suggest that the extract has promising antibacterial properties, especially at higher concentrations. It performed best against *Staphylococcus* and showed comparable activity to Ampicillin for the other two strains at 60 μL. Further research is needed to identify the active compounds in the extract, optimize its potency, and explore its use as a natural antibacterial agent. Prior research done by Sivaraj *et al.*, 2019 revealed that the antibacterial activity of *M. hortensis* leaf methanol extract was examined against both Gram-negative (*Escherichia coli*, *Proteus vulgaris*, *Shigella flexneri*) and Gram-positive (*Bacillus subtilis*, *Staphylococcus aureus*, and *Micrococcus luteus*)[17]. Previous research on the polar extracts of *Millingtonia hortensis* leaves has shown significant antimicrobial activity. The aqueous alcohol extract was tested against 20 bacterial strains and 2 yeast cultures. It showed strong activity, particularly against the Gram-negative bacteria *Escherichia coli* and *Salmonella typhimurium*, with a minimum inhibitory concentration (MIC) of 6.25 μg/ml. The results were comparable to standard antibiotics like gentamycin (for bacteria) and nystatin (for yeast) [24].

CONCLUSION

This study has given preliminary information to determine the chemical composition of *Millingtonia hortensis* L.f. using UV-Vis, FTIR and GC-MS. The phytochemical screening of *Millingtonia hortensis* flower extract using four different solvents revealed the presence of diverse bioactive compounds, including alkaloids, flavonoids, tannins, saponins, and phenolic compounds indicating the plant's rich phytochemical profile. In the present study, 21 out of 101 major chemical constituents are identified from ethanolic flower extract of *Millingtonia hortensis* by Gas Chromatogram-Mass Spectroscopy (GC-MS) analysis. The findings indicate that the ethanolic extract has promising antibacterial capabilities, particularly at higher concentrations. It was effective against *Staphylococcus* and equivalent to Ampicillin for the other two bacteria at 60 μL. The findings support the traditional medicinal use of this plant and highlight its potential as a source of natural antibacterial agents. Further research will include identifying and characterizing the individual bioactive chemicals responsible for the reported antibacterial activity, as well as testing their safety and efficacy in vivo. Therefore, it is suggested that this plant be used as a phytopharmaceutical.

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Table.1: Qualitative phytochemical Analysis of Different Flower Extracts of *Millingtonia hortensis* L.f.

S. No	Bioactive compounds	P. E	B	E	W
1.	Carbohydrates	+	-	+	+
2.	Proteins	+	-	+	+
3.	Lipids	+	-	+	+
4.	Aromatic acid	+	-	+	-
5	Phenols	-	+	+	+





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6.	Flavonoids	-	+	+	+
7.	Alkaloids	+	-	+	+
8.	Terpenoids	-	-	+	+
9.	Steroids	-	+	+	-
10.	Coumarins	-	+	+	-
11.	Tannins	-	-	+	+
12.	Saponins	-	-	+	+
13.	Quinone	+	+	+	-
14.	Anthraquinones	+	-	+	+
15.	Catechins	+	-	+	-

P. E- Petroleum ether B- Benzene E- Ethanol W- Water + Presence – Absence

Table.2: UV-VIS Absorbance Spectrum of *M. hortensis* Ethanolic Flower Extract at Different Wavelengths

S. No	Wavelength (nm)	Absorbance
1.	230	0.366754
2.	286	0.71061
3.	390	0.889314
4.	444	0.879704
5.	566	0.699751
6.	734	0.399134
7.	900	0.254877

Table.3: Structural Analysis of *M. hortensis* Ethanolic Flower Extract by FTIR Spectroscopy

S. No	Observed Band Range	Band Interaction	Band Assignment	Possible compounds
1.	3132.68	Stretch	C- H and O- H	Alkene, alcohol & carboxylic acid
2.	2361.92	Stretch	O- H	Carboxylic acid
3.	1637.43	Stretch	C= O	Amide
4.	1400.28	Bend	C- H	Alkane
5.	1075.43	Stretch	C- N/F	Amino & fluoro compounds
6.	669.16	Bend	C= C	alkene

Table.4: Major Phytochemicals Identified in the Ethanolic Flower Extract of *Millingtonia hortensis* L.f. in GC-MS Analysis

S. No	Retention Time (rt)	Name of the Compound	Molecular Formula	Molecular Weight	Peak Area%
1.	19.061	2- methoxymethyl-2methyl pyrrolidine-1-carboxyaldehyde	C ₈ H ₁₅ NO ₂	157	2.53
2.	19.977	9-oxabicyclo [3.3.1] nonane- 2,6- diol	C ₈ H ₁₄ O ₃	158	1.42
3.	20.869	1- Hydroxy- 4,3'- dimethyl- bicyclohexyl- 3,3'- dien-2-one	C ₁₄ H ₂₀ O ₂	220	21
4.	21.267	Dodecanoic acid, 3- hydroxy-	C ₁₂ H ₂₄ O ₃	216	2.96
5.	23.552	2- methylencyclohexanol	C ₇ H ₁₂ O	112	23.02





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6.	23.923	2H- pyran-2acetic acid, tetrahydro-4hydroxy-6pentyl	C ₁₀ H ₁₈ O ₃	186	5.16
7.	24.312	Cyclobutanecarboxylic acid, decyl ester	C ₁₅ H ₂₈ O ₂	240	2.55
8.	25.744	Dianhydro mannitol	C ₆ H ₁₀ O ₄	146	1.73
9.	33.298	n- Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	3.56
10.	36.466	10E, 12Z octadecadienoic acid	C ₁₈ H ₃₂ O ₂	280	1.91
11.	44.245	9- Tricosene[z]	C ₂₃ H ₄₆	322	1.55
12.	44.876	Heneicosane	C ₂₁ H ₄₄	296	7.04
13.	48.267	1- Heptacosanal	C ₂₇ H ₅₆ O	396	2.00
14.	48.707	Eicosane	C ₂₀ H ₄₂	282	8.20
15.	51.533	9- octadecene-1-01,[z]	C ₁₈ H ₃₆ O	268	1.46
16.	51.935	Eicosane	C ₂₀ H ₄₂	282	4.63
17.	54.446	[6z,9z]- 6,9- pentacosadiene	C ₂₅ H ₄₈	348	1.51
18.	54.775	Tetratetracontane	C ₄₄ H ₉₀	618	2.05
19.	56.700	Docosapentaenoic acid- TMS	C ₂₅ H ₄₂ O ₂	402	1.33
20.	57.465	Beta- sitosterol	C ₂₉ H ₅₀ O	414	3.19
21.	62.318	Thunbergol	C ₂₀ H ₃₄ O	290	1.19


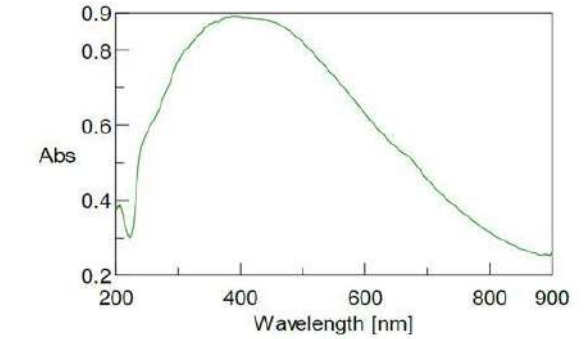
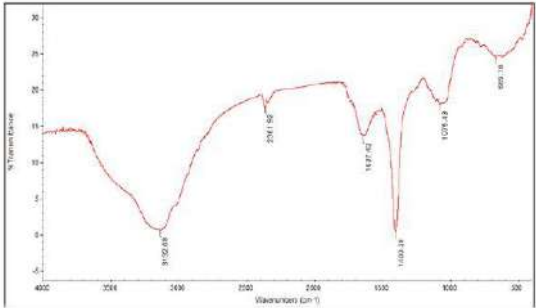
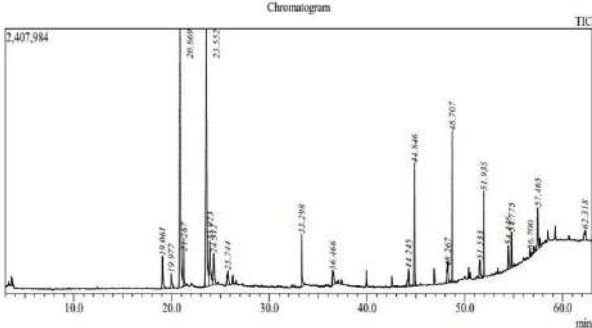

Table.5: Antimicrobial Activity of Ethanolic Flower Extract of *M. hortensis* L.f. Against Bacterial Pathogens

S. No	Bacterial pathogens	Zone of Inhibition (mm)			Standard (Ampicillin)(25µg)
		20µL	40µL	60µL	
1.	<i>Streptococcus pneumonia</i>	5	5.5	6	6
2.	<i>Staphylococcus aureus</i>	5	6	7	6
3.	<i>Pseudomonas aeruginosa</i>	-	5	6	8

Figure 1: Representative tree (*Millingtonia hortensis* L.f.) used for sample collection(Source: Internet <https://exoticflora.in/cdn/shop/products/Millingtonia-hortensisef.jpg?v=1639168341>)Figure 2: Sample collection and extraction a) Collection of *M. hortensis* flower b) Drying in shade for about one week c) Coarse powder of dried flower d) Solvent extraction method



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Figure. 3: Ethanollic Flower Extraction	Figure. 4: UV-Vis Analysis of Ethanollic <i>M. hortensis</i> Flower Extract
	
Figure .5: FTIR Spectra of Ethanollic Flower Extract of <i>M. hortensis</i>	Figure. 6: GC-MS Chromatogram of Ethanollic <i>Millingtonia hortensis</i> L.f. Flower Extract
	
Figure. 7: Antimicrobial Activity of Ethanollic Flower Extract of <i>Millingtonia hortensis</i> L.f. Against Bacterial Pathogens	





Review on Yellow Spotted Millipede *Harpaphe haydeniana*

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ABSTRACT

A range of studies have explored the diversity and distribution of millipedes, including the yellow spotted millipede. Chen [1] and Patil [2] both identified new species in their respective studies in China and India, while Boccardo [3] and Bogyó[4] focused on the habitat and seasonal variations in millipede populations in Brazil and Hungary. These studies collectively contribute to our understanding of the yellow spotted millipede's ecological role and its potential as a bioindicator of environmental health. In India, particularly in the Western and Eastern Ghats, Patil [2] and Ramanathan [5] has revealed a rich diversity of species. Hence, the present study focus on the importance and application of the yellow millipede collected from various literature available in google scholar.

Keywords: These studies collectively contribute to our understanding of the yellow spotted millipede's ecological role and its potential as a bioindicator of environmental health.

INTRODUCTION

Millipedes, while generally harmless, can become a nuisance when they invade homes in large numbers, potentially contaminating food and causing respiratory problems for those with allergies. They are particularly attracted to damp areas, and their presence can be a sign of excess moisture in the home. To address infestations, it is recommended to wait for a few days for the problem to subside and then vacuum the remaining bodies, while also removing debris and sealing openings around the foundation. If problems persist, insecticides may be used. Insight Pest Solutions offers millipede extermination services to address these issues [6]. The yellow spotted millipede, a non-native species, has been introduced to various locations, including Arkansas, Louisiana, Oklahoma, Texas, India



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and Singapore [7, 8]. These millipedes are known to have arrived in non - native sites via potted plants and compost from greenhouses [7]. They are most commonly found in the order Polydesmida, which produces the brightest fluorescence under ultraviolet light [9]. Despite being a pest of potatoes in some areas, no pathogenic microorganisms have been found in these millipedes [10].

MILLIEPEDE IN A BIRDS EYE VIEW

The yellow spotted millipede, a member of the Chelodesmidae and Paradoxosomatidae families, has been found in canola cultivation in Brazil [11]. In Australia, the 'Ommatoiulus moreleti' millipede is a nuisance pest, with activity patterns influenced by climatic conditions [12]. Fossil evidence of millipedes, including the *Sinosomaluopingense*, has been found in the Middle Triassic Luoping biota of China [13]. In the Kalahari, millipedes exhibit unique behaviors and ecological adaptations, such as burrowing and surface activity after rainfall [14]. Research on the yellow spotted millipede in India is limited, with most studies focusing on other millipede species. Verma[15] identified various pests of pearl millet in India, but did not specifically mention the yellow spotted millipede. Ramanathan [5] and Alagesan [16] both conducted studies on millipede diversity and distribution in different regions of Tamil Nadu, but did not specifically mention the yellow spotted millipede. Gour[17] studied the diversity of millipedes in the Amravati region of Maharashtra, but also did not specifically mention the yellow spotted millipede. Therefore, there is a gap in the literature regarding the overall view of the yellow spotted millipede in India.

CLASSIFICATION OF MILLIEPEDE

The yellow spotted millipede, a member of the class Diplopoda, is a diverse and ecologically important group of arthropods [18]. It is found in various habitats, including Jamaican caves [19] and the Yintiaoling National Natural Reserve in Southwest China [1]. The species is not considered a pest in the cultivation of canola in Brazil [20].

TAXONOMIC POSITION

The millipede belongs to the kingdom Animalia, class diplopoda, order polydesmida and family Xystodesmidae. The Genus *Harpaphe* and Species: *Harpaphe haydeniana* [21].

RESEARCH IN INDIA

Research on millipedes in India, particularly in the Western and Eastern Ghats, has revealed a rich diversity of species [2, 5]. The presence of *Trigoniulus corallines* in both regions suggests a potential overlap in their habitats [2, 5]. Similarly, the Alagar Hills Reserve Forest in Tamil Nadu has been found to host a variety of millipede species, with mid-elevations being particularly rich in diversity [16]. However, specific information about the yellow spotted millipede in India is not provided in these studies, indicating a need for further research [22, 16, 23, 2] Fig - 1. The yellow-spotted millipede, *Harpaphe haydeniana*, is a common bug found in the moist forests along the Pacific coast [24]. These millipedes have long dark brown or black bodies with contrasting yellow spots down their sides and are known for having multiple body segments, each containing two pairs of legs [25]. Females usually consist of 31 pairs of legs while males have 30 [25]. The activity of these millipedes is influenced by environmental conditions, with a change in activity rhythm observed in late summer and autumn [12]. They play an important role as detritivores in the ecosystem [25].

DIVERSITY OF MILLIEPEDE IN INDIA

Research on millipede diversity in India has revealed a variety of species in different regions. In the Yelagiri hills of Tamil Nadu, 10 species were identified, with the genus *Arthrosphaera* being dominant [26]. Similarly, the Sirumalai Hills in Tamil Nadu were found to host 8 species, with differences in species composition across elevations [5]. The Alagar Hills Reserve Forest, also in Tamil Nadu, showed a peak in millipede diversity at mid-elevations, with specific species being more abundant at 450m [16]. In the Chandoli National Park in Western Maharashtra, a higher diversity of millipedes was found, influenced by less habitat disturbance and food availability [23]. These studies collectively highlight the rich and varied millipede diversity in India, with specific species being more prevalent in certain regions and elevations.



**Vijaydharssani and Horne Iona Averal****MILLIPEDE HABITAT AND PREVENTION STRATEGIES**

Yellow-spotted millipedes, which are harmless to humans, prefer damp and cooler environments and feed on organic debris. They can become an annoyance, especially if there is an invasion near your home. To prevent this, it is recommended to reduce moisture and seal potential entry points. Removing attractants, such as decaying plants and keeping the home clean can also help. In severe infestations, professional pest control services may be necessary [6].

MEDICINAL USES OF YELLOW SPOTTED MILLIPEDE

The yellow spotted millipede, a species found in India, is known for its medicinal uses. Sahu [28] and Mistry [26] both highlight the diverse medicinal applications of various plants and natural resources in India, suggesting that the millipede may also have medicinal properties. The Paite tribe of Manipur, as documented by Devi [29], uses a variety of plants for dermatological healthcare, indicating a potential use for the millipede in skin treatments. Similarly, Yuhlung [30] discusses the use of indigenous medicinal plants by the Maring tribe, Manipur suggesting that the millipede may have traditional medicinal uses in these communities. Further research is needed to explore the specific medicinal properties of the yellow spotted millipede.

ENVIRONMENTAL USES IN INDIA

A significant part of the forest ecosystem in India, plays a crucial role in the turnover of organic matter and the availability of minerals in its habitat [31]. However, its specific environmental uses in India, particularly in relation to pearl millet, are not explicitly discussed in the available literature. Further research is needed to explore the potential applications of the yellow spotted millipede in the context of pearl millet and other agricultural practices in India.

IMPACT OF POLLUTANT IN THIS SPECIES

The studies by Akkari, & Voigtlaender, [32] and Farfan [33] both highlight the ability of certain invertebrates, such as the midgefly and specific millipede species, to survive in polluted environments. This suggests that the yellow spotted millipede may also have a high tolerance for pollutants. However, the specific impact of pollutants on this species is not directly addressed in the available literature. Further research is needed to understand the potential effects of pollutants on the yellow spotted millipede.

MILLIPEDES AS A FOOD FOR TRIBALS IN INDIA

The use of the yellow spotted millipede by tribals in India is not directly addressed in the provided research papers. However, Enghoff [34] and Patil [2] provide valuable information on the nutritional value and diversity of millipedes, respectively. Lever [35] discussed that the irritant exudation from a centipede, has anti-parasitic effect, which may be relevant to the use of millipedes by tribals. Patil [36] highlights the use of wild animal parts, including millipedes, by tribals in Nandurbar district, Maharashtra, for medicinal purposes. This suggests that the yellow spotted millipede may have traditional medicinal uses among tribals in India.

CONCLUSION

The present study focusses on the review of the yellow spotted millipede *Harpaphe Haydeniana*. The diversity and the economic importance were discussed. In India, different species were identified and which showed a good diversity in Western and Eastern Ghats. From various literature it has been proved that tribes lived in India used the yellow spotted millipede as food as well as medicine. But research need to explore in this site to know the full pledged medicinal properties of this organisms. Hence it was concluded that further research is need to be conducted in yellow spotted millipede.





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Figure 1 - Yellow-spotted millipede, *Harpaphe Haydeniana*





Metagenomics and Fungal Identification: Exploring Fungal Diversity through Genomic Insights

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ABSTRACT

Fungi represent a critical component of diverse ecosystems, playing pivotal roles in nutrient cycling, symbiosis, and pathogenesis. Metagenomics, the study of genetic material recovered directly from environmental samples, has revolutionized fungal identification and taxonomy, providing an unprecedented ability to detect, classify, and study fungi without the need for cultivation. This review explores the current advances, challenges, and future perspectives in metagenomics-based fungal research. Metagenomics methodologies, including DNA extraction, amplification techniques, and sequencing technologies, which enable the comprehensive analysis of fungal communities across various environments such as soil, water, and clinical samples. Bioinformatics challenges related to fungal metagenomics, such as the lack of complete fungal reference databases and issues with taxonomic and functional annotation, are discussed in detail. Additionally, we highlight the complexity of fungal genomes, which includes large sizes, repetitive sequences, and horizontal gene transfer, complicating genomic analyses. Despite these challenges, the potential of metagenomics to address ecological and clinical questions is vast. This review also explores future directions, such as the integration of multi-omics approaches to provide deeper insights into fungal biology, the role of emerging sequencing technologies in improving genome resolution, and the expansion of reference databases. Furthermore, we discuss the growing applications of metagenomics in synthetic biology, where fungal enzymes and pathways offer promising industrial and therapeutic possibilities. Through these advancements, metagenomics is poised to significantly enhance our understanding of fungal diversity and its applications in various fields.

Keywords: Metagenomics, fungus, genomics, diversity, sequencing





INTRODUCTION

Metagenomics is a revolutionary field that has transformed our understanding of microbial communities[1]. By directly sequencing the genetic material extracted from environmental samples, metagenomics bypasses the limitations of traditional culturing methods, allowing us to explore the vast and largely uncultured microbial world. This approach has been particularly impactful in the study of fungi, a diverse kingdom of organisms that play crucial roles in ecosystems, human health, and industry[2]. Fungal identification has traditionally relied on morphological characteristics and laborious culturing techniques. However, these methods often fail to capture the full diversity of fungal communities, as many species are difficult to grow in the laboratory[3]. Metagenomics, with its culture-independent approach, offers a powerful alternative for unraveling fungal diversity. By targeting specific fungal genes, such as the internal transcribed spacer (ITS) region of ribosomal DNA, metagenomics can identify a wide range of fungal species, including those that are rare or unculturable[4]. The Internal Transcribed Spacer (ITS) region is the gold standard for fungal identification. Other markers, such as LSU and SSU rRNA genes, complement ITS for phylogenetic studies[5]. Figure 1 shows the different application of metagenomics in fungus research. This combination of metagenomics and targeted gene sequencing has opened up new avenues for fungal research, enabling us to explore fungal diversity in various environments[6]. Metagenomics has revealed the astonishing diversity of fungal communities in different habitats like soil, water, human microbiome etc[7]. By analyzing metagenomic data, researchers have discovered numerous new fungal species, expanding our knowledge of fungal taxonomy and evolution. Metagenomics has provided insights into the ecological functions of fungi, such as nutrient cycling, plant-microbe interactions, and bioremediation[8]. By studying the fungal communities associated with human diseases, metagenomics can aid in the diagnosis, treatment, and prevention of fungal infections. Metagenomics has revolutionized fungal identification, providing a powerful tool for exploring the hidden diversity of this important kingdom[9]. By applying metagenomic techniques deeper understanding of the fungal world and its impact on our planet and human health can be studied.

Metagenomic Analysis of Fungi

The accuracy of metagenomic studies begins with the collection of representative environmental samples. Common sources include soil, water, air, and host-associated environments. Proper sample preservation and extraction methods, such as bead-beating and enzymatic lysis, are essential to obtain high-quality fungal DNA[10]. Advancements in sequencing technologies have significantly impacted fungal metagenomics. Second-Generation Sequencing (SGS). Platforms like Illumina provide high-throughput sequencing with short reads, suitable for amplicon-based studies[11]. Third-Generation Sequencing (TGS) technologies like Oxford Nanopore and PacBio enable long-read sequencing, improving genome assembly and resolving complex fungal genomes[12]. List of sequencing technologies along with their applications and limitations have been shown in table 1. Bioinformatics pipelines are crucial for analyzing metagenomic data, providing the computational foundation to unravel the complexity of fungal communities from environmental samples. These pipelines involve multiple stages and specialized tools tailored to achieve specific goals in fungal metagenomics[13]. Taxonomic classification is essential to identify the composition of fungal communities at various taxonomic levels (phylum, genus, or species). QIIME2 (Quantitative Insights Into Microbial Ecology 2) is a widely used platform for processing and analyzing sequence data, QIIME2 integrates quality filtering, clustering, and taxonomic assignment. It supports fungal community analysis using Internal Transcribed Spacer (ITS) sequences, a popular fungal barcode[14]. MEGAN (MEtaGenome Analyzer) a versatile tool that visualizes metagenomic datasets and assigns taxonomic ranks by comparing sequences to databases such as NCBI or UNITE. MEGAN is particularly useful for exploring fungal diversity and phylogeny[15]. List of metagenomics tools used for taxonomic and functional analysis have been described in table 2. Functional annotation aims to predict the roles of fungal species in the ecosystem or host environment. FUNGuild is a powerful tool for guild-based classification of fungal functional groups, FUN Guild maps OTUs (Operational Taxonomic Units) or ASVs (Amplicon Sequence Variants) to ecological roles such as saprotrophs, pathogens, or symbionts[16]. PICRUSt (Phylogenetic Investigation of Communities by Reconstruction of Unobserved States) originally developed for bacteria, PICRUSt has been used for fungi analysis also. It predicts metabolic



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pathways and gene functions based on reference databases and phylogenetic information[17]. Assembly and binning are critical for reconstructing fungal genomes and organizing them into discrete genomic bins for downstream analysis. MetaSPAdes is a metagenome-optimized genome assembler, MetaSPAdes is designed to handle fragmented fungal genomes, producing high-quality assemblies by stitching overlapping reads[18]. It is effective for recovering entire fungal genomes from complex datasets. MetaBAT tool is used for binning assembled sequences into genome bins based on sequence composition and co-abundance patterns. MetaBAT is useful for identifying specific fungal genomes from mixed community data, which is particularly challenging due to the complex and repetitive nature of fungal genomes[19].

Applications of Metagenomics in Fungal Research

Metagenomics has emerged as a powerful tool for investigating fungal diversity and function across various fields. This section outlines key applications of metagenomics in fungal research. Table 3 shows the various application of metagenomics in fungal research. Metagenomics has revolutionized the study of fungi by enabling comprehensive analysis of fungal communities, their functions, and their interactions with various environments. One of the primary applications is in fungal diversity and taxonomy, where high-throughput sequencing techniques, such as 16S and ITS rRNA sequencing, facilitate the identification and classification of fungal species across ecosystems, such as soil, water, and plant roots[20]. Another critical area is fungal pathogen detection, where metagenomic shotgun sequencing and DNA barcoding are used to identify fungal pathogens in clinical, agricultural, and environmental samples, such as detecting *Aspergillus* in respiratory infections[21]. In the field of fungal bioremediation, metagenomic tools help uncover fungal species capable of degrading pollutants, offering solutions for environmental cleanup. For example, specific fungal strains have been identified for the biodegradation of toxic compounds in polluted soils[22]. Similarly, fungal metabolite profiling utilizes metagenomics and metabolomics to explore secondary metabolites for drug discovery and industrial applications, leading to the identification of novel antimicrobials and anticancer compounds[23]. The role of fungi in human health is another emerging focus, with mycobiome studies revealing how fungal communities in the gut or on the skin influence autoimmune diseases and other health conditions. In agriculture and ecology, the study of fungal symbiosis and fungal ecology reveals how fungi interact with plants, animals, and microbial communities, aiding stress tolerance and nutrient cycling[24].

Finally, metagenomics contributes to fungal functional genomics and evolutionary studies, enabling the annotation of fungal genes involved in metabolism and pathogenesis and tracing the evolutionary history of fungi. These diverse applications demonstrate the transformative potential of metagenomics in advancing fungal research and addressing ecological, medical, and industrial challenges[25]. Table 4 summarizes the key roles of metagenomics analysis in the context of various fungal diseases. It includes a range of fungal diseases, such as invasive fungal infections (e.g., *Aspergillus*, *Candida*, *Pneumocystis*), chronic respiratory infections, and fungal microbiome studies in the human gut and environment. Metagenomics methods employed (primarily Metagenomic Next-Generation Sequencing - mNGS and 16S rRNA gene sequencing), and highlights the significant contributions of metagenomics in each case. These contributions include direct pathogen detection, improved diagnosis: Enhanced patient management, novel pathogen discovery, understanding fungal ecology [39]. Metagenomics has emerged as an indispensable tool for advancing fungal research across diverse fields. By providing a culture-independent approach to studying fungal communities, metagenomics has revolutionized our understanding of fungal diversity, ecology, and function. Metagenomics has revolutionized our understanding of fungal diversity in diverse ecosystems other application of metagenomics in fungal research has been enlisted below.

1. **Soil Microbiomes:** Numerous studies have employed metagenomics to characterize fungal communities in soils. These studies have elucidated the roles of fungi in crucial ecosystem processes such as nutrient cycling (carbon, nitrogen, phosphorus), decomposition, and soil health. For example, metagenomic analyses have revealed the presence of novel fungal taxa involved in the degradation of complex organic matter and the formation of soil aggregates[40].
2. **Marine Ecosystems:** Metagenomic investigations have expanded our knowledge of fungal diversity in marine environments, including oceans, estuaries, and coastal areas. These studies have uncovered unique fungal



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species and lineages adapted to the marine environment, highlighting their potential roles in biogeochemical cycles and marine food webs[41].

3. **Clinical Mycology:** Metagenomics is transforming the field of clinical mycology by enabling the rapid and accurate identification of fungal pathogens, particularly those that are difficult to culture using traditional methods[42].
4. **Direct Pathogen Identification:** Techniques such as shotgun metagenomics allow for the direct identification of fungal pathogens from clinical samples (e.g., blood, tissue, respiratory fluids). This approach is particularly valuable for the diagnosis of rare or emerging fungal infections and for identifying mixed infections caused by multiple fungal species[43].
5. **Improved Disease Management:** Metagenomic data can provide insights into the virulence factors and drug resistance mechanisms of fungal pathogens, aiding in the development of more effective antifungal therapies[44].
6. **Bioremediation:** Metagenomic analyses can identify novel fungal species with the ability to degrade environmental pollutants, such as hydrocarbons, pesticides, and heavy metals. These fungi can be exploited for bioremediation strategies to clean up contaminated sites[45].
7. **Crop Protection:** Understanding the fungal communities associated with plants, including both beneficial and pathogenic fungi, has important implications for crop protection. Metagenomic studies can help identify beneficial fungi that can be used as biocontrol agents against plant diseases, enhance plant growth and development, and improve crop productivity[46].

Challenges in Metagenomics-Based Fungal Identification

Metagenomics technique faces several challenges, particularly in the areas of DNA extraction, amplification, bioinformatics, and genome complexity. Addressing these challenges is crucial for improving the accuracy and resolution of metagenomic fungal studies. Fungal DNA extraction from environmental samples, such as soil, plant roots, or clinical specimens, is often hindered by the presence of contaminants like bacterial DNA, humic substances, and other inhibitors[47]. These contaminants can interfere with the efficiency of DNA extraction, leading to biased representation of fungal communities. Additionally, the diversity of fungal species within a sample can complicate DNA amplification. Common DNA extraction methods are not always optimized for fungal cells, especially those with tough cell walls, such as *Chytridiomycota* and *Zygomycota*[48]. Furthermore, amplification biases introduced by primers, particularly in rRNA gene-based approaches, may skew the representation of fungal communities. To overcome these limitations, advancements in DNA extraction protocols tailored specifically for fungal biomass, as well as improved amplification strategies, are essential[49]. One of the most significant challenges is the lack of comprehensive fungal reference databases, which hampers accurate taxonomic and functional annotation. The current databases often suffer from incomplete or uneven representation of fungal species, particularly those from underexplored environments. This leads to misidentifications or failed annotations when analyzing complex fungal communities[50]. Additionally, the development of standardized pipelines for fungal metagenomic analysis is still in its infancy. Variability in data processing methods, such as read assembly, binning, and taxonomic assignment, results in inconsistencies and challenges in reproducibility across studies. Improved algorithms that are specifically designed to handle the unique aspects of fungal genomes, including their high diversity and low representation in public databases, are critical to advancing the field[51]. Fungal genomes exhibit considerable complexity, characterized by their large size, repetitive sequences, and the frequent occurrence of horizontal gene transfer (HGT). These features pose significant hurdles for accurate genome assembly and annotation. The repetitive nature of fungal genomes can complicate de novo assembly efforts, often leading to fragmented contigs and incomplete genome representations[52]. Furthermore, HGT between fungi and other organisms, including bacteria and plants, further complicates the interpretation of genomic data. This adds an additional layer of complexity in discerning evolutionary relationships and functional roles of fungal genes. To address these challenges, novel sequencing techniques, more refined assembly algorithms, and improved strategies for dealing with HGT are needed[53].



**Ruchi Yadav****Future Directions**

Despite the challenges, metagenomics holds great promise for advancing our understanding of fungal biology and ecology. Several emerging trends and technologies offer the potential to overcome current limitations and open new avenues for research[54]. One of the most exciting future directions in metagenomics is its integration with other omics approaches, such as transcriptomics, proteomics, and metabolomics. By combining metagenomic data with gene expression profiles, protein function analysis, and metabolite characterization, researchers can obtain a more comprehensive understanding of fungal biology[55]. This multi-omics approach will allow for a holistic view of fungal communities, their functional potential, and their interactions with the environment or host organisms. For example, integrating metagenomic data with transcriptomic and proteomic datasets can help elucidate the functional roles of specific fungal species within complex ecosystems[56]. Emerging sequencing technologies, such as single-cell sequencing and third-generation sequencing (TGS), hold great potential for resolving fungal genomes with greater accuracy and completeness[57]. Single-cell sequencing will allow for the analysis of individual fungal cells, which is especially useful in uncovering the diversity of rare or unculturable species within a sample[58]. TGS platforms, such as PacBio and Oxford Nanopore, offer long-read sequencing that can more effectively resolve complex, repetitive fungal genomes and improve genome assemblies. The development of these advanced sequencing technologies is expected to significantly enhance our ability to conduct in-depth fungal metagenomic studies[59]. Metagenomics has great potential in the field of synthetic biology, particularly in the discovery of novel fungal enzymes and metabolic pathways with industrial and therapeutic applications[60]. Fungi are known to produce a wide range of bioactive compounds, such as enzymes for bioremediation, antibiotics, and immunosuppressive drugs. Through metagenomic mining, novel fungal enzymes with unique properties can be identified, and synthetic biology approaches can be used to optimize their production. Additionally, metagenomics can aid in identifying new biosynthetic pathways for valuable bio-products, providing a sustainable source for industrial applications[61].

CONCLUSION

Metagenomics has revolutionized our understanding of fungal diversity, offering a powerful tool for the identification and characterization of fungi from complex environmental and clinical samples. By bypassing the need for culturing, metagenomic approaches enable the discovery of previously uncharacterized species and provide a more comprehensive picture of fungal communities. The integration of advanced sequencing technologies and bioinformatics tools has facilitated the analysis of vast amounts of genomic data, enhancing our ability to identify fungi at the species and strain levels. The significance of metagenomics in fungal research lies in its potential to uncover the intricate relationships between fungi and their environments, shedding light on their ecological roles and contributions to biodiversity. In the context of human health, metagenomic insights have profound implications, particularly in understanding the pathogenesis of fungal infections, their resistance mechanisms, and their impact on immunocompromised patients. Furthermore, it paves the way for the discovery of novel antifungal targets and the development of precision medicine strategies tailored to specific fungal pathogens. Future of fungal research through metagenomics holds tremendous promise. With the continued advancement of sequencing technologies, bioinformatics tools, and computational approaches, we can expect more precise, efficient, and cost-effective fungal identification. Future research will also focus on refining metagenomic workflows to better integrate multi-omics data, providing a more holistic view of fungal biology and interactions. These advancements will lead to deeper insights into the roles fungi play in both health and disease, fostering the development of innovative therapeutic strategies and environmental management practices.

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Contributions

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Competing Interests

The author declare that they have no conflict of interest.

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Table 1 Metagenomics sequencing technologies along with its application and limitations.

S.No	Sequencing Technology	Read Length	Data Output	Applications	Advantages	Limitations
1	Illumina (SGS)	50-300 bp	High-throughput	Amplicon sequencing, whole-genome sequencing	High accuracy, cost-effective	Short reads, challenging for complex genomes
2	PacBio (TGS)	>10,000 bp	Moderate	Genome assembly, resolving repeats	Long reads, improved genome assembly	Higher error rate, expensive





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3	Oxford Nanopore (TGS)	Up to 2 Mb	Moderate	Real-time sequencing, metagenome assembly	Portable, long reads, real-time analysis	High error rate, costly for large-scale studies
4	Ion Torrent (SGS)	200-600 bp	High-throughput	Targeted sequencing, small genome assembly	Fast turnaround, suitable for targeted studies	Limited by read length, sequencing errors
5	Sanger Sequencing	500-1000 bp	Low-throughput	Validation, single-gene studies	High accuracy, gold standard for validation	Labor-intensive, low throughput

Table 2 Bioinformatics tools used for taxonomic and functional analysis for metagenomics data

S.No	Tool	URL	Application	Analysis Type
1	QIIME2	https://qiime2.org	Assigns taxonomic ranks to fungal sequences.	Taxonomic Analysis
2	MEGAN	http://ab.inf.uni-tuebingen.de/software/megan	Assigns taxonomic ranks to fungal sequences.	Taxonomic Analysis
3	FUNGuild	http://www.stbates.org/guilds/app.php	Predicts fungal metabolic pathways.	Functional Analysis
4	PICRUSt	https://github.com/picrust/picrust2	Predicts fungal metabolic pathways.	Functional Analysis
5	MetaSPAdes	https://cab.spbu.ru/software/meta-spades/	Facilitates assembly of fungal genomes.	Assembly and Binning
6	MetaBAT	https://bitbucket.org/berkeleylab/metabat/src/master/	Facilitates binning of fungal genomes.	Assembly and Binning

Table 3 Application of metagenomics in fungal research along with sequencing techniques used.

S.No	Application	Description	Key Techniques Used	Example/Use Case
1	Fungal Diversity and Taxonomy	Identification and classification of fungal species in various environments using DNA sequencing.	High-throughput sequencing (HTS), 16S rRNA sequencing	Mapping fungal diversity in soil or plant roots.
2	Fungal Pathogen Detection	Identification of fungal pathogens in clinical, agricultural, or environmental samples.	Metagenomic shotgun sequencing, DNA barcoding	Detection of <i>Aspergillus</i> species in clinical infections.
3	Fungal Bioremediation	Study of fungal communities involved in environmental cleanup, such as degradation of pollutants.	Metagenomic sequencing, functional annotation	Fungal strains for biodegradation of toxic compounds in polluted soils.
4	Fungal Metabolite Profiling	Analysis of fungal secondary metabolites for drug discovery and industrial applications.	Metagenomic sequencing, metabolomics	Identifying novel antimicrobial or anticancer compounds.
5	Mycobiome in Health	Exploring the role of fungal communities in human health, especially in the gut or on the skin.	Shotgun metagenomics, 18S rRNA sequencing	Studying the gut mycobiome in relation to autoimmune diseases.
6	Fungal Symbiosis	Investigating mutualistic	Metagenomics, RNA	Understanding fungal





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		interactions between fungi and plants, animals, or other microorganisms.	sequencing	endophytes in plants and their role in stress tolerance.
7	Fungal Evolution and Phylogeny	Tracing evolutionary relationships of fungi based on genomic data.	Phylogenetic analysis, shotgun sequencing	Phylogenetic tree construction of fungal species from environmental samples.
8	Fungal Functional Genomics	Functional annotation of fungal genes to understand their roles in metabolism, pathogenesis, etc.	Metagenomic functional annotation	Characterizing genes involved in lignocellulose degradation in fungi.
9	Fungal Ecology and Microbiomes	Understanding fungal interactions in microbial communities in diverse ecosystems (soil, water, etc.).	Metagenomics, 18S rRNA sequencing	Investigating fungal dynamics in forest soils and their impact on carbon cycling.

Table 4 Role of Metagenomics Analysis in understanding fungal diseases.

S.No	Fungal Disease	Metagenomics Method	Role of Metagenomics Analysis	Reference
1	Invasive Fungal Infections (e.g., Aspergillus, Candida, Pneumocystis)	Metagenomic Next-Generation Sequencing (mNGS)	Direct pathogen detection, bypassing culture limitations, enabling rapid diagnosis.	[26,27]
2	Invasive Pulmonary Aspergillosis	mNGS	Early and accurate diagnosis, improved patient management.	[28]
3	Pneumocystis Pneumonia	mNGS	Detection of Pneumocystis jirovecii, especially in immunocompromised patients.	[29]
4	Candidemia	mNGS	Identification of Candida species, including emerging resistant strains.	[30]
5	Chronic Respiratory Infections	16S rRNA gene sequencing, shotgun metagenomics	Understanding the complex interplay of fungi in chronic lung diseases.	[31]
6	Fungal Microbiome in Human Gut	16S rRNA gene sequencing, shotgun metagenomics	Investigating the role of fungi in gut health and disease.	[32]
7	Fungal Microbiome in Environment	Shotgun metagenomics	Assessing environmental factors contributing to fungal infections.	[33]
8	Cryptococcosis	mNGS	Detection of Cryptococcus neoformans and C. gattii, especially in immunocompromised individuals.	[34]
9	Histoplasmosis	mNGS	Diagnosis of Histoplasma capsulatum infection, particularly in endemic regions.	[35]
10	Coccidioidomycosis	mNGS	Detection of Coccidioides immitis and C. posadasii, improving diagnostic accuracy.	[36]
11	Mucormycosis	mNGS	Identification of Mucorales species, crucial for timely antifungal	[37]





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			treatment.	
12	Paracoccidioidomycosis	mNGS	Diagnosis of Paracoccidioides brasiliensis infection, especially in endemic areas.	[38]

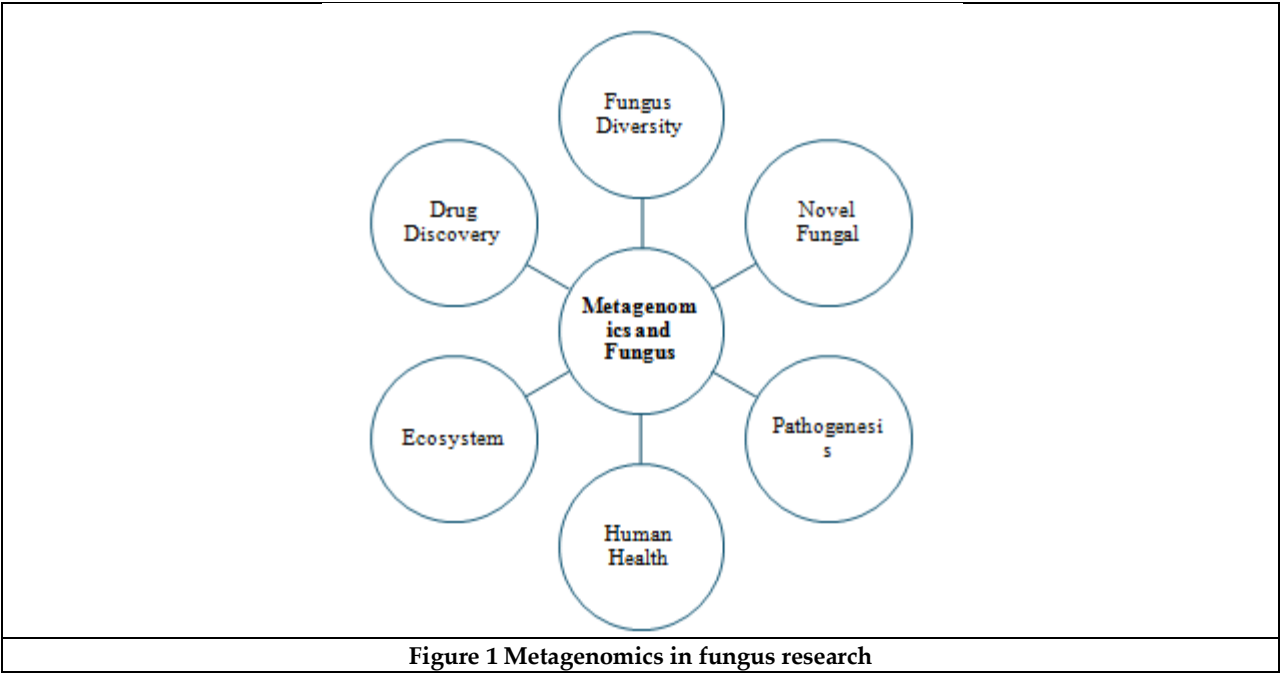


Figure 1 Metagenomics in fungus research





Exploring Antibacterial and Antioxidant Properties of Nanoceria Synthesized from *Tamarindus indica* Fruit Shell Extract for Biomedical Applications

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ABSTRACT

Green nanotechnology seeks to develop nanomaterials and products that are environmentally benign and safe for human health, while also addressing environmental challenges through innovative nanoproducts. The instability of residues from chemicals not produced by chemical synthesis necessitates the advancement of green chemistry in nanoparticle fabrication. The objective of this study was to synthesize and characterize cerium oxide nanoparticles (CeO₂NPs) from ethanol extracts of *Tamarindus indica* and evaluate their antibacterial efficacy against *Staphylococcus aureus* and other Gram-positive coagulase-positive cocci. The optical characteristics, crystallinity, dimensions, and morphology of the biosynthesized nanoparticles were evaluated using UV-Vis spectroscopy, FTIR (Fourier Transform Infrared Spectroscopy), and SEM (Scanning Electron Microscopy). The synthesis and characterization of cerium oxide nanoparticles (rare earth elements) were analyzed in an environmental study, which revealed that a more environmentally sustainable process could be identified even at the laboratory scale. This work concluded that cerium oxide nanoparticles may be produced utilizing extracts from ridge gourd shells. This method provides environmentally beneficial alternatives to more dangerous processes, while also fostering pollution avoidance through the synthesis of nanoparticles in their natural environments. The current research indicates that the produced cerium oxide nanoparticles may serve as an antioxidant activity and antibacterial agent against many pathogenic microorganisms.

Keywords: *Tamarindus indica*, Antibacterial activity, DPPH assay and Pathogenic organism.



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INTRODUCTION

The objective of the multidisciplinary field of nanotechnology is to create materials with enhanced atomic, molecular, and supramolecular properties. Abdelrahman, G.H *et al.*, 2019) assert that nanomaterials are employed in microelectronics, glucose detection, DNA and RNA analysis, heavy metal detection, disease diagnosis, and disease management. Metal nanoparticles can be synthesized using several physical, chemical, and biological methods. The synthesis of nanoparticles using bacteria, fungi, algae, yeast, and plants is referred to as the "biological method". The narrow size distribution of nanoparticles is a benefit of physical and chemical methods; nevertheless, the main disadvantages are high energy, time, and cost requirements, along with the usage of dangerous substances (Ain, Q.U *et al.*, 2023). Biological technologies provide numerous advantages over conventional methods, including high yields, low prices, absence of downstream processing, and environmental sustainability. Additionally, an alternative term for the biological processes is "green synthesis." Consequently, the synthesis of nanoparticles by plant extracts offers a simple, single-step reduction process suitable for large-scale production. Numerous research indicate that plant extracts exhibiting significant biological activity can be utilized to synthesize nanoparticles (Agarwal *et al.*, 2018).

Phytomining is the technique of utilizing plant extracts to convert metal ions into nanoparticles. Research on plant extracts for the synthesis of nanoparticles has been prevalent in recent years. Assert that plant extracts function as stabilizing, capping, and reducing agents. Plant-derived materials, such as leaves, stems, roots, shoots, flowers, bark, seeds, and there by products, have been successfully utilized for the creation of nanoparticles (Aly, S.H, *et al.*, 2023). Similarly, *Tamarindus indica*, a long-lived evergreen hardwood tree found in various countries/regions, such as Egypt, Africa (tropical region), and Asia (including India), is used for medicinal purposes. *Tamarindus indica* trees produce a large amount of green fruits. When green fruit fully ripens on the tree, it becomes a paste-like texture (brown/reddish brown color). And the fruit will become sweet and sour. Over time, every part of the tree has been used in the Ayurvedic medicinal system for its nutritional benefits. For example, tree pulp was employed as an ayurvedic element for both skin detoxification and body polishing (Anokwah, D *et al.*, 2022). Furthermore, Tamarind paste has antimicrobial characteristics, hence it was commonly used to treat wounds. According to a World Health Organization report, tamarind fruits contain the majority of necessary amino acids.

The importance of biomedical applications of CeO₂ has recently grown due to their ability to provide protection against radiation, toxicant-induced cellular damage, and various pathological conditions, including brain or heart ischemia, neurological disorders, and retinal neurodegeneration. CeO₂ exhibits low solubility in water, leading to challenges in biological applications. Multiple studies have demonstrated that nanomaterial polymer coatings improve stability, biocompatibility, and water solubility; for instance, dextran-coated nanoceria displays antioxidant properties (Bagevadi, Z.K *et al.*, 2019). Nanoceria is emitted into the atmosphere as a result of extensive utilization, raising significant concerns regarding human exposure, primarily through inhalation. The literature on the toxicity of CeO₂ presents inconsistent results. Doping cerium dioxide nanoparticles with various elements can alter their optical, electrical, structural, and biomedical properties (Baliyan, S *et al.*, 2022).

Hence, in the current study, we collected and extracted the rare earth cerium oxide nanoparticles from *Tamarindus indica* fruit shells were synthesized using a chemical method using methanol solvents, respectively. The samples were characterized through UV-spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), and SEM analysis. The antibacterial and antioxidant activities of the samples were also examined.

Experimental Section

Plant Material

Fruit shells of *Tamarindus indica* were procured from Thiruvkanager village, Tirupattur, Tirupattur District, Tamil Nadu, India, based on cost-effectiveness, accessibility, and medicinal properties. Shells of *Tamarindus indica* were



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locally sourced, meticulously cleaned with tap water and subsequently with distilled water to eliminate dust and extraneous elements, then cut into small fragments, air-dried, and ground into powder for subsequent application.

Extraction of Plant Material

The methanol extract of *Tamarindus indica* fruit shell was obtained by combining 10 g of fruit shell powder with 100 ml of deionised water in a 250 ml Erlenmeyer flask. The mixture was thereafter cooked on the hot plate at 60 °C for 20 minutes. The produced solution was first filtered via standard filter paper to remove undesirable components, followed by filtration with Whatman filter paper No. 1 (Bhadoriya, S.S *et al.*, 2011). Finally the prepared compound of extracts was denoted as TIFs. The filtered extract served as the reducing and stabilising agent in the creation of nanoparticles.

Synthesis of Cerium Oxide Nanoparticles

The first visual confirmation of the green synthesis of Cerium Oxide Nanoparticles utilising fruit shell extract came from observation. The shell extract was subjected to a Cerium ion solution, resulting in the formation of Cerium Oxide Nanoparticles. A 0.1M solution of Cerium (III) Nitrate Hexahydrate (CAS No: 10294-41-4) was acquired from Sigma-Aldrich, USA. Cerium Oxide Nanoparticles were synthesised by dissolving 25.2 grams of $(\text{Ce}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O})$ cerium in 50 ml of double-distilled water and swirling for 20 minutes. Simultaneously, an aqueous extract of fruit shell was prepared by incorporating 1 gram of shell powder into 50 ml of double-distilled water. This mixture was vigorously agitated using a magnetic stirrer for 30 minutes at 60 °C until completely dissolved, followed by filtration through Whatman No. 1 filter paper. Thereafter, the Cerium (III) Nitrate solution was incrementally introduced to the fruit shell extract hull solution and agitated vigorously for 6-8 hours at 60 °C. Initially, the reaction mixture appeared brown, subsequently changing to yellow, indicating the creation of cerium oxide nanoparticles (C. Godugu, A *et al.*, 2023). The yellow powder was ultimately acquired, signifying the presence of Cerium oxide nanoparticles was recommended in Figure 1.

Characterization of Cerium Oxide Nanoparticles

UV-Vis Spectrophotometer

A double beam UV-visible spectrophotometer was used to analyze the reduction of Cerium ions in Cerium oxide nanoparticles at various wavelengths between 300 and 700 nm. The Perkin Elmer Spectrophotometer, which has a resolution of 1 nm, was used to perform this research.

Fourier Transform Infrared Spectroscopy

FTIR was used to analyze the phytochemical components of fruit shell powder and the functional groups of artificially produced Cerium Oxide nanoparticles (SHIMADZU instrument). Using KBr pellets, the materials were ground, and their FTIR spectra were measured between 4000 and 400 cm^{-1} .

Scanning Electron Microscopy

The extracted powdered material was coated with gold ions using an ion coater set at 0.1 Torr pressure, 20 mA current, and 70 s coating time. SEM used a 15 kV accelerating voltage to visualize the subsurface structure. The Leica stereo scan-440 scanning electron microscope was used to evaluate the SEM measurements. The produced nanoparticles' size and shape are shaped in part by the SEM data.

Antibacterial activity by agar well diffusion method

The antibacterial efficacy of rare earth cerium oxide nanoparticles derived from methanol extracts of *Tamarindus indica* fruit shells was evaluated against pathogenic bacterial strains, specifically *Bacillus subtilis*, *Escherichia coli*, *Salmonella*, and *Staphylococcus aureus*. The bacterial cultures were cultivated in Mueller Hinton Agar (Himedia) (figure 2). Antibacterial activity was assessed using diffusion disc plates on agar, with approximately 0.1 mL of each bacterial culture spread across the agar plate surfaces. For the antibacterial assay, all bacterial strains were incubated in Mueller Hinton Broth (Himedia) for 24 hours at 37°C and subsequently plated on Mueller Hinton Agar (Himedia) for agar diffusion experiments. Paper discs (6 mm in diameter) were positioned on the agar medium to absorb



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cerium oxide nanoparticles from 100 μL of peel extracts of *Tamarindus indica* fruit shell. Inhibition diameters were assessed following incubation for 24 to 48 hours at 37°C . In this study, Gentamycin (100 $\mu\text{g/ml}$) served as the positive control, while DMSO was utilized as the negative control to assess the sensitivity of the bacterial culture (Breijyeh, Z *et al.*, 2020). Different amounts of methanol extracts, prepared identically, from selected samples are utilized to assess antibacterial activity.

Antioxidant Activity

The antioxidant efficacy of the extracts was assessed utilizing DPPH free radical scavenging techniques. A stock solution of 1 mg/mL of cerium oxide nanoparticles derived from *Tamarindus indica* fruit shell extract and ascorbic acid was prepared by dissolving in methanol. DPPH (Diphenyl-2-picryl hydrazyl radical) - 1 mM Three milliliters of 1 mM DPPH in methanol was combined with 100 microliters of peel extracts at concentrations of 20, 40, 60, 80, and 100 microliters (V. Kalyanaraman *et al.*, 2019). The DPPH solution in methanol served as a positive control (ascorbic acid), whereas methanol alone functioned as a blank. The solution was incubated for 30 minutes at ambient temperature, and the absorbance was recorded at 680 nm utilizing a UV-visible spectrophotometer. When DPPH interacts with the antioxidant in the sample, the color transitions from deep purple to pale yellow (Biswas, S.K *et al.*, 2016). Each assay was conducted in triplicate. The proportion of radical scavenging activity for each plant extract at various dilutions was determined using the subsequent equation:

$$\text{DPPH radical \% inhibition} = [(C(\text{OD}) - S(\text{OD})) / C(\text{OD})] \times 100$$

Here, optical density (OD) refers to the absorbance of a methanolic solution of DPPH, which serves as the control. S (OD) represents the absorbance of the test sample, which includes cerium oxide NPs from fruit shell extracts and ascorbic acid; together with DPPH. The ranges of IC_{50} values were also determined.

RESULTS AND DISCUSSION

UV-Visible spectroscopy analysis

The UV Vis Spectrophotometer is an effective instrument for assessing the optical properties of synthesised Cerium Oxide Nanoparticles. The UV spectrum of appropriate sample was analysed within the range of 200-1000 nm. The UV-Vis absorption spectrum indicates a surface plasmon resonance band centred at 302 nm, which is a characteristic peak for Cerium Oxide Nanoparticles (Figure 3). The process demonstrates the reduction of Cerium ions to form metallic rare earth nanoparticles within the reaction mixture. The SPR band was generated as a result of the excitation of free electrons in the Cerium Oxide Nanoparticles upon the absorption of visible light. A single peak was observed, indicating the formation of spherical-shaped nanoparticles. The broadened peak displayed indicates that poly-dispersed nanomaterials, synthesised using tamarind fruit shells, were reported by Ashraf *et al.* (2016). A comparable outcome was documented in the synthesis of Cerium Oxide Nanoparticles by Ben Ayed, A *et al.*, (2022).

Fourier Transform Infrared (FT-IR) Spectroscopic Analysis

FTIR Spectrum is used to determine the presence of organic molecules on the surface of Nanoparticles. In this present investigation, an FTIR measurement was used to identify phytochemical present in fruit shell extract responsible for reduction of rare earth cerium oxide nanoparticles.

The FT-IR analysis revealed the following absorption peaks: 3425 cm^{-1} , 2499 cm^{-1} , 2192 cm^{-1} , 1626 cm^{-1} , 1461 cm^{-1} , 1371 cm^{-1} , 1330 cm^{-1} , 1041 cm^{-1} , 811 cm^{-1} , 734 cm^{-1} , and 575 cm^{-1} . The O-H stretching of alcohol is represented by peaks at 3425 cm^{-1} . The band at 2499 cm^{-1} indicates the stretching of the H-C=O bond in aldehydes. The C=C stretching of the conjugated alkene is indicated by peaks at 2192 cm^{-1} and 1626 cm^{-1} . The presence of alkene C-H bending is indicated by a peak at 1461 cm^{-1} , along with an additional peak at 1371 cm^{-1} corresponding to the same bending mode. The presence of aromatic amine C-N stretching is evidenced by the band observed at 1330 cm^{-1} . The C-O stretching of aliphatic ether is indicated by a peak at 1041 cm^{-1} . Sharp bands observed at 811 and 734 cm^{-1} correspond to potent nitro compounds in the asymmetric stretch. The 825 cm^{-1} peak indicated the presence of vinyl bond tri-substituted alkenes, whereas the 575 cm^{-1} peak was associated with bromo alkanes, which were significant in





the synthesis of rare earth cerium oxide nanoparticles (Figure 4). The following results exhibit similarity to T. N. Ravishankar et al., 2015.

Scanning Electron Microscope (SEM) Analysis

The geomorphology of CeO₂ NPs was examined using SEM, revealing a spherical shape. The SEM image of CeO₂ NPs, exhibiting a spherical shape, resulted from the interaction of CeN₃O₉.6H₂O with the peel extract of *Tamarindus indica* over a duration of 6 hours, as illustrated in Figures-5. The typical SEM images of nanoceria clearly illustrate a significant presence of spherical shapes with a narrow size distribution. The low-resolution image confirms that the shapes were synthesised in substantial quantities, with individual nanoparticle sizes approximately 30 nm, exhibiting a uniform and spherical morphology. These results are consistent with earlier studies (Muruganantham Chelliah et al., 2012).

To identify the cerium oxide nanoparticles in methanol extracts of *Tamrandius indica* fruit shells, antibacterial activity was evaluated using the traditional agar well diffusion method (Table 1). The extracts were made at the identical amounts using 2% DMSO (dimethyl sulfoxide) as a negative control. The test microorganisms *Bacillus subtilis* and *Escherichia coli* were seeded into the proper Mueller-Hinton agar medium using the spread plate technique. The plate was then incubated at 37°C for 24 hours. The antibacterial activity was assessed by measuring the diameter of the inhibitory zone that developed around the well (Brindhadevi, K et al., 2023).

The prepared cerium oxide nanoparticles exhibit antibacterial activity against both gram-positive and gram-negative bacteria (figure 6). Four types of organisms were utilized in this study *Salmonella*, *Escherichia coli*, *Bacillus subtilis*, and *Staphylococcus aureus*. *Staphylococcus aureus* and *Bacillus subtilis* are classified as gram-positive bacteria, while *Salmonella* and *Escherichia coli* are identified as gram-negative bacteria for this experimental research work. (Manandhar, S et al., 2019).

Figure 7 illustrates that *Bacillus subtilis* exhibited a gradual rise in the zone of inhibition, beginning at 17 mm at 50 µg/ml and reaching a maximum of 25 mm at 100 µg/ml, in comparison to the positive control (15 mm). *Escherichia coli* exhibited comparable outcomes, with the inhibition zone expanding from 17 mm at 50 µg/ml to 25 mm at 100 µg/ml. This was similarly analogous to the activity of Gentamicin. *Salmonella* had a somewhat reduced escalation in the zone of inhibition, varying from 18 mm at 50 µg/ml to 21 mm at 100 µg/ml. *Staphylococcus aureus* exhibited a significant enhancement in antibacterial efficacy, with the zone of inhibition escalating from 17 mm at 50 µg/ml to 25 mm at 100 µg/ml, exceeding the positive control's 14 mm inhibition. The results demonstrate that the chemical exhibits dose-dependent antibacterial efficacy against all examined species, with increased concentrations leading to greater zones of inhibition (Asowata-Ayodele, A.M et al., 2016). DMSO served as a negative control for the inhibitory zone of the produced drug.

Antioxidant activity

Antioxidants protect cells from damage inflicted by free radicals. Antioxidants have been shown to inhibit or mitigate the oxidation of other compounds. By removing radical intermediates and undergoing self-oxidation, they possess the capability to halt chain reactions and avert oxidation processes. The body contains substances that can mitigate the damage inflicted by free radicals or inhibit their formation. Edible substances and therapeutic flora are abundant in natural antioxidants. These plant-derived nanomaterials, specifically nanoceria antioxidants such as carotenoids and polyphenols, exhibit diverse biological effects. To explore potential sources of antioxidants and encourage their application in functional foods, pharmaceuticals, and food additives, it is crucial to efficiently extract antioxidants from food and medicinal plants and assess them accurately (Agidew, A et al., 2023).

From the figure 8 showed the DPPH radical scavenging activity results indicated that the methanol cerium oxide nanoparticles derived from *Tamarindus indica* fruit shell extract exhibited IC₅₀ values of 20 µg and 42.5 µg for the control ascorbic acid and aqueous extract, respectively. The antioxidant activity of cerium oxide nanoparticles is illustrated in Fig 2. These extracts have demonstrated significant efficacy as DPPH radical scavengers. Blainski, A et



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al., 2013 employed the concentration of the sample and standard that achieved 50% inhibition of free radicals to calculate the IC₅₀ values. The antioxidant efficacy of *Tamarindus indica* extracts was assessed by the DPPH radical scavenging method. DPPH is a widely utilized free radical compound for assessing the scavenging activity of various samples of free radicals. The method provides advantages of speed, simplicity, and cost-effectiveness, while also delivering direct data on the overall antioxidant capacity of the test system (Camele, I *et al.*, 2019).

CONCLUSION

Recent literature demonstrates that synthetic nanoceria have emerged as a significant category of nanomaterials for many industrial and medical applications. The extract of *Tamarindus indica* fruit shell utilized for nanoceria synthesis is effective, economical, environmentally sustainable, and suitable for large-scale production. The UV-Vis spectrum displays a distinct absorption peak for cerium oxide nanoparticles at 302 nm. The FTIR analysis revealed absorption bands associated with the primary functional groups in the natural fruit shell extract. The substantial decrease in response time attained by the use of fruit shell extract is a pivotal outcome of the biosynthesis approach, unlike other nanoparticle manufacturing techniques that are now more rapid and reproducible. Scanning electron microscopy revealed that the produced nanoparticles are spherical and around 20–30 nm in diameter. Additionally, *in vitro* antibacterial efficacy against multidrug-resistant Gram-positive and Gram-negative isolates. It exhibited synergistic effects with conventional antibiotics, hence decreasing their minimum inhibitory concentrations (MICs). The DPPH assay demonstrated that cerium oxide nanoparticles exhibited free radical scavenging capacity, with IC₅₀ values of 20 µg for ascorbic acid and 42.5 µg for the aqueous extract, respectively. Recent research suggest that cerium oxide nanoparticles obtained from the fruit shell of *Tamarindus indica* may serve as potential therapeutic and environmental agents.

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Conflict of Interest: Nil

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Table 1: Antibacterial activity of CeO₂ NPs from TIFs

S.No	Organisms	NC (DMSO)	PC (Gen)	Zone of Inhibition		
				50 µg/ml	75 µg/ml	100 µg/ml
1.	<i>Bacillus subtilis</i>	—	15 mm	17 mm	19 mm	25 mm
2.	<i>Escherichia coli</i>	—	15 mm	17 mm	19 mm	25 mm
3.	<i>Salmonella</i>	—	15 mm	18 mm	20 mm	21 mm
4.	<i>Staphylococcus aureus</i>	—	14 mm	17 mm	22 mm	25 mm



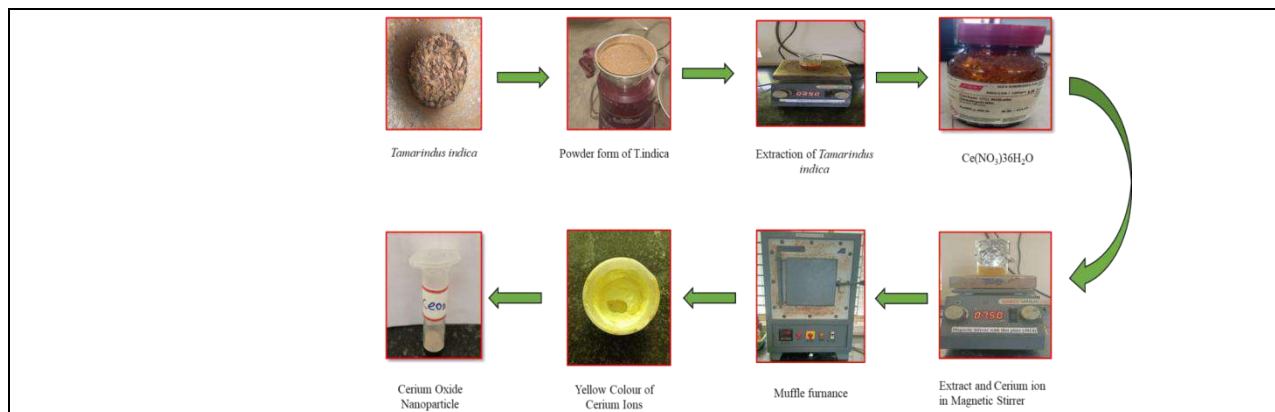
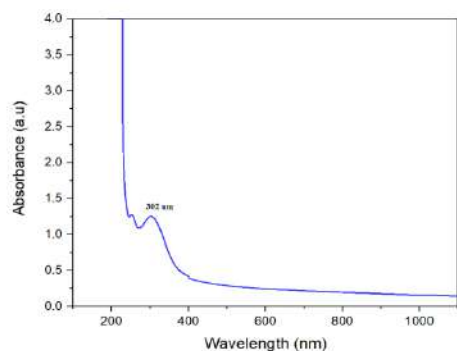
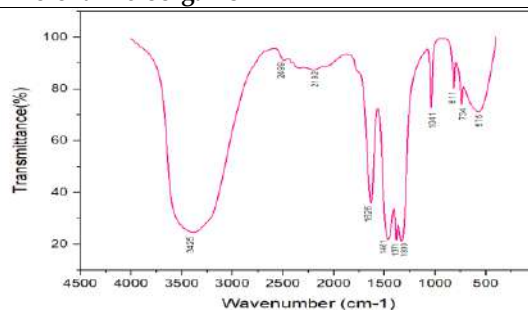
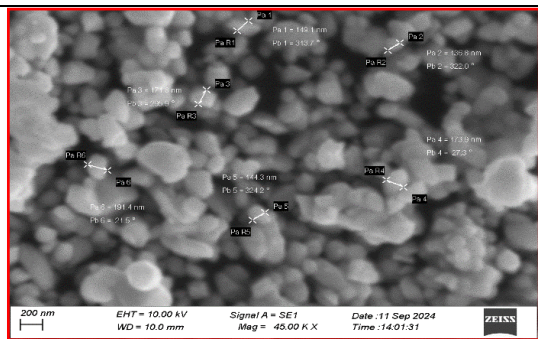
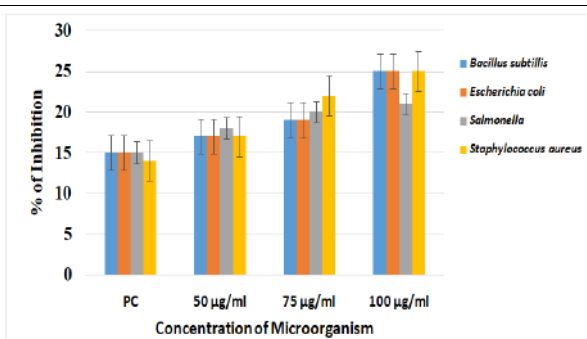
Fig. 1 Schematic illustration for the synthesis of CeO₂ NPs

Fig.2 Sub cultures of different microorganism

Fig.3 UV-Vis spectrum CeO₂ NPs nanoparticles from TIFsFig.4 FTIR spectrum of CeO₂ NPs nanoparticles from TIFsFig.5 SEM analysis of CeO₂ NPs nanoparticles from TIFsFig 6: Graphical Representation of antibacterial activity of CeO₂ Nanoparticles



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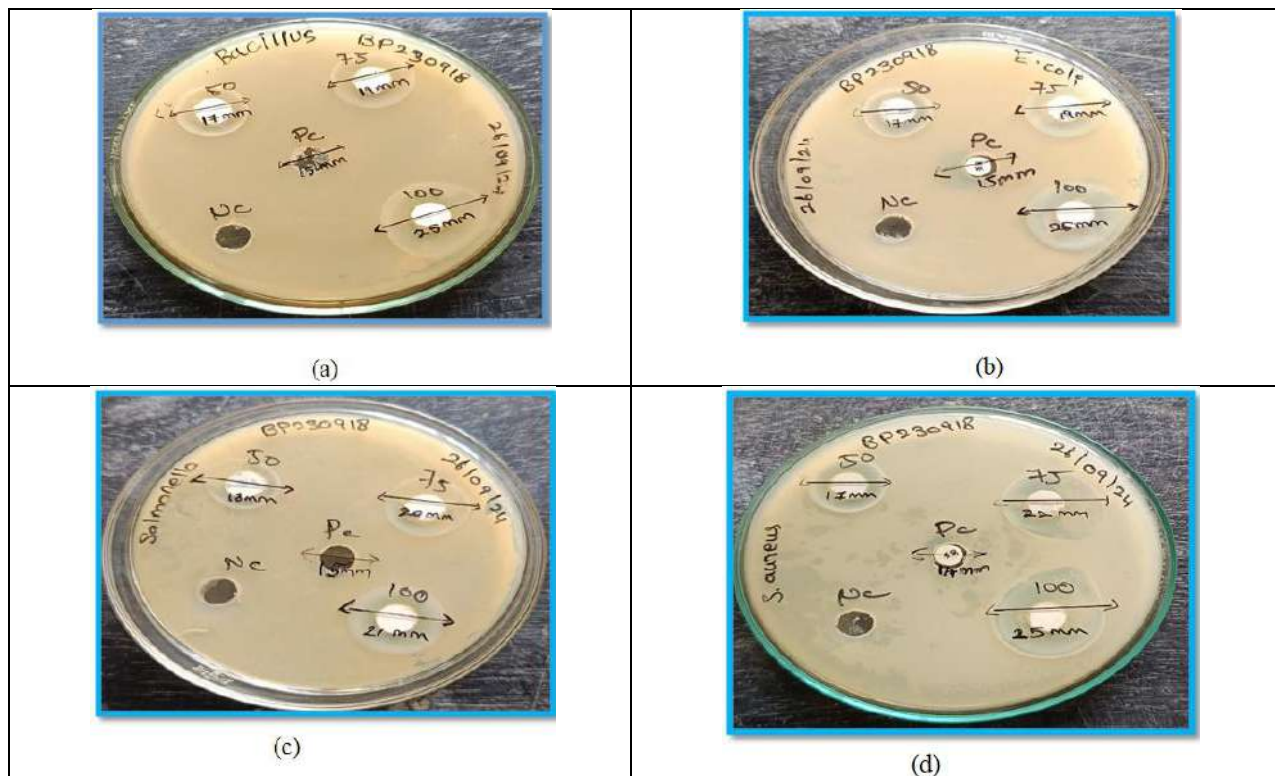


Fig. 7 Antibacterial Activity of CeO_2 NPs (a) *Bacillus subtilis* (b) *Escherichia coli* (c) *Salmonella* (d) *Staphylococcus aureus*

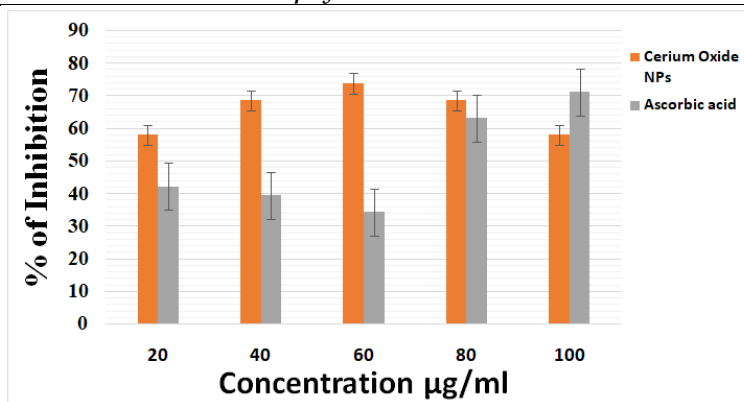


Fig. 8 Antioxidant Activity of CeO_2 NPsnanoparticles from TIFs





RESEARCH ARTICLE

Evaluating Medicinal Plant Importance and Community use Patterns in Korampallam Village, Thoothukudi District, Tamil Nadu

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ABSTRACT

There is an incredible reservoir of ethnobotanical expertise in Korampallam village, in particular concerning the usage of medicinal vegetation in number onefitness care. The following findings were made clear. An ethnobotanical survey was made in the Korampallam village in Thoothukudi district, Tamil Nadu, India during the month of January 2020. Based on the literature review, about 14 categories of common ailments like Kidney Disease (KD), Skin disease (SD), Hair problem (HP), Stomach problem (SP), Respiratory disease (RD), Cold (C), Cough (CO), Diuretic (D), Tooth ache (TA), Head ache (HA), Fever (F), Body heat (BH), Insect Bite (IB) and Menstrual issues (MI) were selected for the present survey. Among 14 major disease categories, dermatological disorders were dominated followed by kidney disease with 451 use-reports, followed by skin disease and hair problem (302 and 242 use-reports, respectively). From the finding it was shown that hair problem was noted with the highest ICF value of 0.98 Highest RCF value of 2.84 was noted for *Azadirachta indica* which was followed by *Ocimumtenuiflorum* with 1.16 and *Cynodondactylon* with 1.14 RCF value. To treat cold and cough *Ocimum tenuiflorum* and *Justicaadhatoda* were greatly used. *Cynodondactylon* (75%) and *Azadirachta indica* (52%) showed highest FL for treating diuretic issues. Based on ROP value *Azadirachta indica* is widely used species with the RPL of 90%. Current research work suggests that priority research projects in this area should be planned for the pharmacological evaluation and conservation of medicinal plants in this field.

Keywords: Ethnobotany, Korampallam, FL, ICF, RCF, ROP, RPL





INTRODUCTION

People have persistently utilized therapeutic plants to bargain with themselves and combat maladies. In all memorable civilizations and on all landmasses, one uncovers strains of this utilize [1]. Ethnobotany offers with the coordinate pursuing of plant life with man. The term has regularly been considered synonymous with either financial botany or with conventional pharmaceutical [2]. The present study explained the plant differences of Kormapallam, Thoothukudi district, Tamil Nadu, India. The area has a rich variety of flowers with medicinal value and important economic benefits. These flowers are commonly used by the local population for various purposes. The goals of the display consider incorporate ethnobotanical study utilizing Google form and quantitative examination of therapeutic plants.

MATERIALS AND METHODS

Description of the study area

Korampallam village was the area selected for the present analysis. Korampallam is a panchayat village located in Tamil-Nadu state, India, in the Thoothukudi district. The Korampallam geographical coordinates are latitude 8.77° N and longitude 78.1° E

Medicinal Plants Survey

The medicinal plants study of the village includes the testing of knowledge about the usage of common medicinal plants. Based on the literature review, about 14 categories of common ailments like Kidney Disease (KD), Skin disease (SD), Hair problem (HP), Stomach problem (SP), Respiratory disease (RD), Cold (C), Cough (CO), Diuretic (D), Tooth ache (TA), Head ache (HA), Fever (F), Body heat (BH), Insect Bite (IB) and Menstrual issues (MI) were selected for the present survey. A questionnaire was prepared using Google forms to collect the ethnobotanical applications of the plants in the village. The link was then circulated among the residents of the chosen village.

Quantitative analysis of ethnobotanical data [3]

Informant consensus factor (ICF).

The Informant Consensus Factor (ICF) value reflects the level of agreement among informants on the use of medicinal plant species and assesses variations in their modes of utilization for reported diseases. A high ICF value, approaching 1, signifies that widely recognized plant species are commonly used by local communities, indicating their reliability and effectiveness in treating diseases.

$$ICF = \frac{Nur - Nt}{Nur - 1}$$

Where, "Nur" is the total number of use reports for each disease category, "Nt" indicates the number of species used in said category.

Use value (UV)

The Use Value (UV) measures the relative significance of plant species based on their various uses, reflecting their importance in traditional practices.

$$UV = \frac{\sum U}{N}$$

Where "UV" represents the use value of an individual species, "U" denotes the total number of recorded uses for that species, and "N" refers to the number of informants who reported its use.

Relative frequency of citation (RFC)

The Relative Frequency of Citation (RFC) represents the local significance of each species within a study area. It is calculated by dividing the number of informants who mention a species (FC) by the total number of informants in the survey (N).





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$$RFC = \frac{FC}{N} (0 < RFC < 1)$$

Fidelity level (FL).

The **Fidelity Level (FL)** represents the percentage of informants who reported the use of a specific plant species for treating a particular ailment within a study area.

$$FL\% = \left(\frac{NP}{N} \right) * 100$$

Where "NP" represents the number of informants who reported using a specific plant species for a particular disease, and "N" is the total number of informants who cited the species for any disease. A higher **Fidelity Level (FL)** indicates a greater frequency and strong preference for using that plant species to treat a specific ailment among the informants in the study area.

Relative popularity level (RPL)

The Relative Popularity Level (RPL) is calculated as the ratio of the number of ailments treated by a specific plant species to the total number of informants citing any disease. The RPL value ranges from 0 to 1, where 1 indicates that the plant is widely recognized for treating major ailments, while 0 signifies no reported medicinal use for any ailment.

Rank order priority (ROP).

The Relative Optimal Popularity (ROP) is a correction factor used to appropriately rank plant species based on their Fidelity Level (FL) and Relative Popularity Level (RPL). It is calculated by multiplying the RPL and FL values, ensuring a more precise assessment of the plant's significance in traditional medicine.

$$ROP = FL \times RPL$$

RESULT AND DISCUSSION

Informant consensus factor (ICF):

To calculate ICF, the said illnesses had been first categorized into 14 unique ailment classes on the premise of the literature review. Among 14 major disease categories, from the finding it is shown that hair problem is noted with the highest ICF value of 0.98 which may be due to the water used in the area. This has been shown in Table 1. Similar findings have already been reported in the ethnobotanical survey of medicinal plants commonly used by Kani tribals in Tirunelveli hills of Western Ghats, India[4]. However, Indigenous and tribal people in Rangamati, Bangladesh [5] and medicinal plants used in Terai forest of western Nepal. This has also been defined greater range of species to deal with gastrointestinal illnesses as compared to dermatological ailments[6].

Relative frequency of citation (RFC) and use value (UV):

The RFC and UV indices are carried out to pick capacity plant species for similarly pharmacological examine and advice in drug development. The RFC of the stated species ranged from 0.1 to 2% (Table 2). Highest RCF value of 2.84 was noted for *Azadirachta indica* which is followed by *Ocimum tenuiflorum* with 1.16 and *Cynodon dactylon* with 1.14 RCF. The plant species with excessive RFC ought to be subjected to pharmacologic, phytochemical, and different organic research to assess and show their authenticity[7]. The use value (UV) index demonstrates the relative significance of plant species and households for a population. In the present investigation, the UV of the reported medicinal plant species varied from 0.01 to 0.2 as shown in Table 2. The highest UV was observed for *Azadirachta indica* with 0.20 followed by *Ocimum tenuiflorum* and *Cynodon dactylon* with the value of 0.08. These findings reveal the substantial use of above stated species with inside the remedy of diverse illnesses with the aid of using neighbourhood inhabitants/healers and the awareness of indigenous peoples, which makes such medicinal plants, the primary desire to deal with a disease[8].





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Relative popularity level (RPL)

Our 123 informants referred to 48 plant species for 14 one-of-a-kind disorder categories. They are given in Table 2. *Azadirachta indica* is considered to be popular plant of that area due to their higher RPL value of 0.9 which is closely followed by *Acacia nilotica*, *Achyranthes aspera* and *Bryophyllum calycinum* with the RCF value of 0.6 each. These findings had been in regular with preceding research at the repute of medicinal plant life amongst Bedouins of Negev district[9] and medicinal plant survey in Palestinian area[10].

Rank order priority (ROP)

The Rank order priority (ROP) index is used to rank correctly the plant species with special FL values. The ROP values are therefore received are given in Table 2. Of the forty eight species, best 5 species attained ROP above 50. The ROP values mentioned for medicinal vegetation utilized by Bedouins network in Negev district and in Palestinian location had been similar to give findings[10].

Fidelity level (FL)

The constancy fee is an vital way to peer for which disease a selected species is greater effective. It suggests the informants' preference for every disease and the ability of the species associated with the ailments. The FL of plant species for precise sicknesses within the gift have a look at location is proven in Table 3. The medicinal plant life which can be extensively utilized by the human beings of the RCF have better FL values than the ones which can be much less popular. On the alternative hand, greater medicinal plant life which can be referred to as treatments of a unmarried aliment have a 100% FL than the ones which can be used as treatments for multiple kind of aliment[11].

CONCLUSION

There is a top notch reservoir of ethnobotanical information in Korampallam village, particularly concerning using medicinal flora in number one fitness care. It is well documented in the current findings that the *Azadirachta indica* plant is the most popular plant and traditional claim of that region which are now ready to be pharmacologically further investigated, which would lead to the discovery and development of natural drugs. Current research work suggests that priority research projects in this area should be planned for the pharmacological evaluation and conservation of medicinal plants in this field.

FUTURE SCOPE

The current study aided in the identification of regionally significant medicinal plant species that are used to cure various illnesses, contributing significantly to the region's ethnobotany. To identify active chemicals that can be employed for drug discovery, additional phytochemical and pharmacognostic analysis of these species will be performed.

Declaration

Acknowledgement

I wish to acknowledge the people of Korampallam village, Thoothukudi, Tamil Nadu, India for their constant support and help.

Conflict of Interest

We the authors of this paper declare no potential conflict of interest.

Author's Contribution

Dr. S. Beulah Jerlin – helped me in selecting this problem and helped me to visit the Korampallam village.

Ms. S. Pauline Jenifer – I carried out this project by visiting, collecting, analysis of data and documentation.





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Table: 1 Informant Consensus Factor (ICF) Values by Category for Treating Various Diseases

S. No	Category	Plant Species Used and Number of Citations	Total number		ICF
			Species	Use citation	
1	Kidney Disease (KD)	Abutilon indicum (16), Acacia nilotica (9), Achyranthes aspera (14), Aerva lanata (55), Alternanthera ficoidea (21), Anisomelesmalabarica (5), Azadirachta indica (16), Bacopa monnieri (16), Cardiospermum halicacabum (13), Carica papaya (13), Cissus quadrangularis (11), Citrullus colocynthis (8), Citrus limon (35), Cocos nucifera (11), Cynodondactylon (48), Datura metal (16), Hibiscus rosinensis (5), Phyllanthus amarus (28), Tribulus terrestris (26), Bryophyllumcalycinum (23), Centella asiatica (29), Boerhaaviadiffusa (23), Catheranthus roseus (5), Heliotropium indicum (5)	24	451	0.95
2	Skin Disease (SD)	Abutilon indicum (5), Acacia nilotica (5), Achyranthes aspera (12), Azadirachta indica (51), Centellaasiatica (1), Boerhaaviadiffusa (1), Aloe vera (51), Acalyphaindica (70), Calotropis gigantean(6), Eclipta alba (10), Ficusbenghalensis (6), Lawsonia inermis (19), Mangiferaindica (6), Mimosa pudica (6), Tridax procumbens (5), Heliotropium indicum (17)	16	302	0.95





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3	Hair Problem (HP)	Azadirachta indica (35), Citrus limon (43), Hibiscus rosa-sinensis (59), Eclipta alba (34), Leucas aspera (4), Murrayakoengii (67)	6	242	0.98
4	Stomach Problem (SP)	Abutilon indicum (17), Acacia nilotica (8), Achyranthes aspera (6), Azadirachta indica (51), Bacopa monnieri (5), Cardiospermum halicacabum (8), Bryophyllumcalycinum (6), Aloe vera (24), Mimosa pudica (12), Tridax procumbens (2), Cassia fistula (13), Cyperus rotundus (2), Nelumbo nucifera (8), Ricinus communis (10), Solanum nigrum (16), Tamarindus indica (9), Solanum xanthocarpum (6), Asparagus racemosus (16), Murrayakoengii (9)	19	228	0.92
5	Respiratory disease (RD)	Acacia nilotica (14), Achyranthes aspera (10), Citrullus colocynthis (30), Datura metal (12), Bryophyllumcalycinum (11), Solanum torvum (12), Solanum trilobatum (43), Solanum xanthocarpum (25)	8	157	0.96
6	Cold (C)	Acacia nilotica (8), Bryophyllumcalycinum (5), Mimosa pudica (2), Leucas aspera (26), Justiciaadhatoda (37), Solanum torvum (13), Ocimum tenuiflorum (80), Asparagus racemosus (8), Phyla nodiflora (14)	9	193	0.96
7	Cough (CO)	Achyranthes aspera (3), Aerva lanata (5), Datura metal (12), Bryophyllumcalycinum (3), Boerhaaviadiffusa (1), Justiciaadhatoda (66), Ocimum tenuiflorum (65), Phyla nodiflora (7)	8	162	0.96
8	Diuretic (D)	Aerva lanata (8), Azadirachta indica (65), Cynodon dactylon (94), Tridax procumbens (11), Asparagus racemosus (1)	5	179	0.97
9	Tooth ache (TA)	Abutilon indicum (14), Acacia nilotica (15), Achyranthes aspera (14), Acalypha indica (7), Calotropis gigantea (4), Ficus benghalensis (31), Cyperus rotundus (5)	7	90	0.93
10	Head ache (HA)	Abutilon indicum (41), Aervalanata (24), Datura metal (18)	3	83	0.97
11	Fever (F)	Azadirachta indica (52), Carica papaya (43), Cyperus rotundus (3), Catheranthus roseus (4), Phyla nodiflora (2)	5	104	0.96
12	Body Heat (BH)	Azadirachta indica (22), Boerhaaviadiffusa (9), Cyperus rotundus (4), Asparagus racemosus (7), Citrus limon (40), Cocos nucifera (37),	6	42	0.88
13	Insect bites (IB)	Azadirachta indica (33), Cardiospermum halicacabum (21), Bryophyllumcalycinum (2), Aloe vera (14), Calotropis gigantea (42), Leucas aspera (20), Phyla nodiflora (10)	7	219	0.97
14	Menstrual issues (MI)	Alternanthera ficoidea (15), Azadirachta indica (28), Carica papaya (52), Hibiscus rosa-sinensis (47), Mangifera indica (10)	5	152	0.97

Table 2 Ailment Type, Used Value, Relative Frequency of Citation, Relative Popularity Level and Rank Order Priority of Selected Medicinal Plants

S. No	Name of the plant	Ailment Type	UV	RFC	RPL	ROP
1	Abutilon indicum	KD, SD, SP, TA, HA	0.05	0.75	0.5	50
2	Acacia nilotica	KD, SD, SP, RD, C, TA	0.03	0.47	0.6	60
3	Acalypha indica	SD, TA	0.04	0.62	0.2	20
4	Achyranthes aspera	SP, RD, CO, TA	0.03	0.47	0.6	60
5	Aerva lanata	KD, CO, D, HA	0.05	0.74	0.4	40
6	Aloe vera	SD, SP, IB	0.05	0.71	0.3	30




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7	Alternanthera ficoidea	MI	0.02	0.29	0.2	20
8	Anisomelesmalabarica	MI	0.01	0.04	0.1	10
9	Asparagus racemosus	SP, C, D, BH,	0.01	0.25	0.4	40
10	Azadirachta indica	SD, HP, SP, D, F, BH, IB, MI	0.20	0.98	0.9	90
11	Bacopa monnieri	SP	0.01	0.16	0.2	20
12	Boerhaaviadiffusa	CO, BH	0.01	0.27	0.4	40
13	Bryophyllumcalycinum	IB	0.02	0.40	0.6	60
14	Calotropis gigantea	SD, TA, IB	0.02	0.41	0.3	30
15	Cardiospermum halicacabum	KD, SP, IB	0.02	0.33	0.3	30
16	Carica papaya	KD, F, MI	0.06	0.87	0.3	30
17	Cassia fistula	SP	0.01	0.10	0.1	10
18	Catheranthus roseus	KD, F	0.01	0.07	0.2	20
19	Centella asiatica	KD, SD	0.01	0.24	0.2	20
20	Cissus quadrangularis	KD	0.01	0.08	0.1	10
21	Citrullus colocynthis	KD, RD	0.02	0.30	0.2	20
22	Citrus limon	KD, HP, IB	0.06	0.95	0.3	30
23	Cocos nucifera	KD, IB	0.02	0.38	0.2	20
24	Cynodondactylon	KD, D	0.08	0.96	0.2	20
25	Cyperus rotundus	SP, TA, HA, F, BH	0.01	0.11	0.4	40
26	Datura metal	KD, RD, CO, HA	0.03	0.46	0.4	40
27	Eclipta alba	SD, HP	0.02	0.35	0.2	20
28	Ficus benghalensis	TA, SD	0.02	0.29	0.2	20
29	Heliotropium indicum	KD, SD	0.01	0.17	0.2	20
30	Hibiscus rosa-sinensis	KD, SP, MI	0.06	0.89	0.3	30
31	Justicaadhatoda	C, CO	0.05	0.83	0.2	20
32	Lawsonia inermis	SD	0.01	0.15	0.1	10
33	Leucas aspera	HP, C, IB	0.02	0.40	0.3	30
34	Mangifera indica	SD, MI	0.01	0.12	0.2	20
35	Mimosa pudica	SD, SP, C	0.01	0.16	0.3	30
36	Murrayakoengii	HP, SP	0.04	0.61	0.2	20
37	Nelumbo nucifera	SP	0.01	0.06	0.1	10
38	Ocimum tenuiflorum	C, CO	0.08	0.96	0.2	20
39	Phyla nodiflora	C, CO, F, IB	0.02	0.26	0.4	40
40	Phyllanthus amarus	KD	0.01	0.22	0.1	10
41	Ricinus communis	SP	0.01	0.08	0.1	10
42	Solanum trilobatum	RD	0.02	0.34	0.1	10
43	Solanum xanthocarpum	RD	0.01	0.25	0.2	20
44	Solanum nigrum	SP	0.01	0.12	0.1	10
45	Solanum torvum	RD, C	0.01	0.20	0.2	20
46	Tamarindus indica	SP	0.01	0.07	0.1	10
47	Tribulus terrestris	KD	0.01	0.20	0.1	10
48	Tridax procumbens	SD, SP, D	0.01	0.14	0.3	30

Kidney Disease - KD, Skin disease - SD, Hair Problem HP, Stomach Problem SP, Respiratory Disease RD, Cold C, Cough CO, Diuretic - D, Tooth Ache – TA, Head Ache - HA, Fever - F, Body Heat - BH, Insect Bite - IB, Menstrual Issues - MI





Table 3 Fidelity Level Percentage of Medicinal Plants Based on Various Categories of Diseases

S. No	Ailment	Plant	FL%
1.	Kidney Disorder	<i>Abutilon indicum</i>	13
		<i>Acacia nilotica</i>	7
		<i>Achyranthes aspera</i>	11
		<i>Aerva lanata</i>	44
		<i>Alternanthera ficoidea</i>	16
		<i>Anisomelesmalabarica</i>	4
		<i>Azadirachta indica</i>	12
		<i>Bacopa monnieri</i>	12
		<i>Boerhaaviadiffusa</i>	18
		<i>Bryophyllumcalycinum</i>	18
		<i>Cardiospermum halicacabum</i>	10
		<i>Carica papaya</i>	10
		<i>Catheranthus roseus</i>	4
		<i>Centella asiatica</i>	23
		<i>Cissus quadrangularis</i>	9
		<i>Citrullus colocynthis</i>	6
		<i>Citrus limon</i>	28
		<i>Cocos nucifera</i>	9
		<i>Cynodondactylon</i>	39
		<i>Datura metal</i>	12
		<i>Heliotropium indicum</i>	4
		<i>Hibiscus rosa-sinensis</i>	4
		<i>Phyllanthus amarus</i>	23
		<i>Tribulus terrestris</i>	21
2.	Skin Disease	<i>Abutilon indicum</i>	4
		<i>Acacia nilotica</i>	4
		<i>Acalypha indica</i>	56
		<i>Achyranthes aspera</i>	9
		<i>Aloe vera</i>	41
		<i>Azadirachta indica</i>	41
		<i>Boerhaaviadiffusa</i>	0.8
		<i>Calotropis gigantean</i>	5
		<i>Centella asiatica</i>	0.8
		<i>Eclipta alba</i>	8
		<i>Ficus benghalensis</i>	5
		<i>Heliotropium indicum</i>	13
		<i>Lawsonia inermis</i>	15
		<i>Mangifera indica</i>	5
		<i>Mimosa pudica</i>	5
		<i>Tridax procumbens</i>	5
3.	Hair Problem	<i>Azadirachta indica</i>	28
		<i>Citrus limon</i>	34
		<i>Eclipta alba</i>	27
		<i>Hibiscus rosa-sinensis</i>	48
		<i>Leucas aspera</i>	3
		<i>Murrayakoengii</i>	54




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4.	Stomach Problem	<i>Abutilon indicum</i>	14
		<i>Acacia nilotica</i>	6
		<i>Achyranthes aspera</i>	5
		<i>Aloe vera</i>	19
		<i>Asparagus racemosus</i>	13
		<i>Azadirachta indica</i>	41
		<i>Bacopa monnieri</i>	4
		<i>Bryophyllumcalycinum</i>	5
		<i>Cardiospermum halicacabum</i>	6
		<i>Cassia fistula</i>	10
		<i>Cyperus rotundus</i>	2
		<i>Mimosa pudica</i>	10
		<i>Murrayakoengii</i>	7
		<i>Nelumbo nucifera</i>	6
		<i>Ricinus communis</i>	8
		<i>Solanum nigrum</i>	13
		<i>Solanum xanthocarpum</i>	5
		<i>Tamarindus indica</i>	7
		<i>Tridax procumbens</i>	2
5.	Respiratory disease	<i>Acacia nilotica</i>	11
		<i>Achyranthes aspera</i>	8
		<i>Bryophyllumcalycinum</i>	9
		<i>Citrullus colocynthis</i>	24
		<i>Datura metal</i>	10
		<i>Solanum trilobatum</i>	35
		<i>Solanum torvum</i>	10
		<i>Solanum xanthocarpum</i>	20
6.	Cold	<i>Acacia nilotica</i>	6
		<i>Asparagus racemosus</i>	6
		<i>Bryophyllumcalycinum</i>	4
		<i>Justicaadhatoda</i>	30
		<i>Leucas aspera</i>	21
		<i>Mimosa pudica</i>	2
		<i>Ocimum tenuiflorum</i>	65
		<i>Phyla nodiflora</i>	11
		<i>Solanum torvum</i>	10
7.	Cough	<i>Achyranthes aspera</i>	2
		<i>Aerva lanata</i>	4
		<i>Boerhaaviadiffusa</i>	0.8
		<i>Bryophyllumcalycinum</i>	2
		<i>Datura metal</i>	9
		<i>Justicaadhatoda</i>	53
		<i>Ocimum tenuiflorum</i>	52
		<i>Phyla nodiflora</i>	6
8.	Diuretic	<i>Aerva lanata</i>	6
		<i>Asparagus racemosus</i>	0.8
		<i>Azadirachta indica</i>	52
		<i>Cynodondactylon</i>	75




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		<i>Tridax procumbens</i>	9
9.	Tooth ache	<i>Abutilon indicum</i>	11
		<i>Acacia nilotica</i>	12
		<i>Acalypha indica</i>	6
		<i>Achyranthes aspera</i>	11
		<i>Calotropis gigantean</i>	3
		<i>Cyperus rotundus</i>	4
		<i>Ficus benghalensis</i>	25
10.	Head ache	<i>Abutilon indicum</i>	33
		<i>Aerva lanata</i>	19
		<i>Datura metal</i>	15
11.	Fever	<i>Azadirachta indica</i>	42
		<i>Carica papaya</i>	35
		<i>Catheranthus roseus</i>	3
		<i>Cyperus rotundus</i>	2
		<i>Phyla nodiflora</i>	2
12.	Body Heat	<i>Asparagus racemosus</i>	5
		<i>Azadirachta indica</i>	18
		<i>Boerhaaviadiffusa</i>	7
		<i>Citrus limon</i>	32
		<i>Cocos nucifera</i>	30
		<i>Cyperus rotundus</i>	3
13.	Insect bites	<i>Azadirachta indica</i>	27
		<i>Aloe vera</i>	11
		<i>Bryophyllumcalycinum</i>	2
		<i>Calotropis gigantea</i>	34
		<i>Cardiospermum halicacabum</i>	16
		<i>Leucas aspera</i>	16
		<i>Phyla nodiflora</i>	8
14.	Menstrual issues	<i>Alternanthera ficoidea</i>	12
		<i>Azadirachta indica</i>	23
		<i>Carica papaya</i>	42
		<i>Hibiscus rosa-sinensis</i>	38
		<i>Mangifera indica</i>	8





Bio prospecting of Crustaceans gut Bacterial Flora from the Coast of Bay of Bengal, Chennai, Tamilnadu

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ABSTRACT

Marine crustaceans offer an abundant supply of biological compounds, giving rise to a diverse array of secondary metabolites with various functional properties. In recent times, marine bacteria have garnered significant attention from the biotechnology sector due to the plethora of bioactive compounds found within them. This research endeavors to investigate and assess the largely unexplored microbiome residing in the intestinal gut of crustaceans for potential biotechnological applications. This microbial consortium will provide more insight and can be harboured in the biotechnology industry for the development of new novel biological agents.

Keywords: Bioprospecting; Crustaceans; Phylogeny; MTT; Sequence and Metabolites





INTRODUCTION

The world oceans comprise a rich diversity of microbial life with current estimates reaching over a million different species. The vast metabolic diversity of marine microorganisms is underpinned by novel enzymatic functions. While marine microorganisms have already proven to be a rich source of biologically active (bioactive) compounds, recent large-scale surveys indicated the existence of thousands of other yet undescribed protein families that provide immeasurable health benefits. Furthermore, there is a growing fascination with marine life, given that products derived from marine organisms often exhibit greater efficacy compared to bioactive compounds sourced from terrestrial environments. This diverse and vast biodiversity fosters high hopes for marine organisms harboring exceptional biochemical attributes and functionally active compounds that hold promise for a wide range of applications. Crustaceans, like crabs, harbor a wealth of advantageous substances, and the gastrointestinal tracts of marine creatures host a multifaceted ecosystem containing distinct microorganisms, encompassing aerobic, facultative anaerobic, and obligate anaerobic bacteria. The gut plays a pivotal role in maintaining the well-being and fostering the growth of the host organism. Given the ongoing evolution of microbial pathogens towards antibiotic resistance, there is a pressing need for the creation of novel and potent antimicrobial compounds. The marine microbiome exhibits the capacity to generate anticancer compounds and secondary metabolites effective against infectious diseases. This study serves as an exploration and investigation into the capacity of marine organisms to serve as sources for the development of marine drugs. Remarkably, the symbiotic microbial communities also demonstrate their potential as reservoirs of bioactive compounds with pharmaceutical applications. Bacteria and fungi have been collected from the exteriors of marine plants and the internal tissues of invertebrates, with a growing focus, especially, on marine fungi.(Numata *et al.*, 1992; Cheng *et al.*, 1994; Kakeya *et al.*, 1995; Takahashi *et al.*, 1995).Meanwhile, oceans also feed millions of populations, simultaneously wastes are damped massively and consistently into the environment. Many scientists (Vicente, F. A *et al.*, 2022, Lanka, S., 2020, Hamed, I *et al.*, 2016) have reported on shells (chitin, chitosan) and marine food waste (hydroxyl compounds) conversion of waste into high-value commercial products. However, the scientific community has surpassed to concentrate on intestinal gut waste generated. All these factors have intended to take up this research on the bioprospecting of crustaceans and exploration microbiome of crustaceans' intestinal gut. The research untangled the new opportunities to a larger extent to acquire knowledge and work on a need of an hour.

MATERIALS AND METHODS

Study area, sample collection and preparation

Randomly crustaceans were accumulated freshly from the coast of the Bay of Bengal, Chennai. The collected crustaceans(crabs) were washed in clean water and crabs were kept in hot water for a few minutes to make their legs to be separated and killed, before dissection (Chandra, S *et al.*, 2018). Crabs were subjected to an abdominal incision using a sterile surgical blade, following which the intestine was carefully dissected and removed. About 15 different species of crustaceans (a variety of crabs) were taken for the study. Samples were prepared by removing the intestinal gut using a sterile surgical blade. Sterile deionized water was used to clean the dissected gut and 1g of the gut was taken for the research.

Microbiological Analysis and Isolation of Bacterial Colony

The optimum conditions required for the growth of gut bacterial flora were maintained using a marine nutrient agar medium. 0.1mL of prepared samples were added to petri plates using the spread plate technique and incubated at 37° C at room temperature for 24 hours. To replicate the conditions of marine water, an equivalent mixture of sterilized marine water and deionized water was incorporated into the medium to preserve the marine environment. Following a 24-hour incubation period, various bacterial colonies were distinguished by their morphology and color. These different colonies were picked and transferred on fresh plates containing the same media to obtain pure culture and incubated for 24 hours at 37°C. Purity was ensured by repeated streaking. Bacterial colonies of distinct appearance were sub-cultured and identified by 16s rRNA (Svanevik, C. Set al., 2017).



**Gomathi et al.,****Extraction of secondary metabolites**

The isolated bacterial strain was cultivated in 100 ml of nutrient broth for 24 hours at 37°C within a rotary shaker, marking the fermentation stage. Subsequently, the cultured broth was subjected to filtration using filter paper, and an equivalent volume of ethyl acetate was introduced into the filtrate. The mixture was separated by vigorous shaking and the separated upper layer was collected and dried. The dried layer was again dissolved with 1 ml of ethyl acetate and the secondary metabolites were extracted out. This extract (test material) is used for further bioassay tests.

Morphology and Biochemical Identification

To determine the identity of bacterial isolates at both the genus and species levels, standard conventional microbiological tests, including gram staining, catalase testing, oxidase testing, IMVIC testing, and sugar fermentation testing, were conducted.

Molecular identification – PCR

Universal primers, specifically designed to bind to the highly conserved region of the 16S rRNA gene, were chosen for this purpose. The reaction mixture contained sample 1µl, forward primer 1µl, reverse primer 1µl, DNase free water 7µl and master mix 10 µl to come to a total reaction mixture of 20 µl. The PCR was conducted in the Eppendorf thermocycler. PCR conditions were set at a total of 35 cycles, to denature at 94 °C, annealing at 58 °C, elongation at 72 °C and final elongation at 72 °C. The amplified 16S rRNA products were subjected to electrophoresis in a 1% agarose gel at 100 volts for a duration of 1 hour. To visualize the amplified bands under UV light, agarose gel was mixed with ethidium bromide (20 µl). About 10µl of DNA sample was mixed with 5µl of gel loading dye and poured into the stamp. The amplification products were captured in photographs under UV light.

Antagonistic activity of bacteria and fungi

Under the aseptic condition, the antagonistic character of fungi and bacteria was tested by the agar well diffusion method at two different concentrations (50µl and 100µl). *Bacillus subtilis* was used as the test organism and the inoculated plates were kept at 37°C for 24 hours. Subsequently, inhibition zone was measured to determine the potent organism and less effective test organisms were excluded. The selected isolates were grown in nutrient broth and incubated at 37°C for 24 hours. Ethyl acetate is added to the culture broth and distilled using a rotary evaporator resulting in a semisolid extract that contains the secondary metabolite. These secondary metabolites will be again utilized for antagonistic activity.

Free radical scavenging activity

The assay was performed by two methods using two different free radicals. The free radical used were 1,1-Diphenyl-2-picrylhydrazyl (DPPH) and ABTS (2,2-azino bis 3-ethyl benzthiazoline -6-sulphonic acid). In the DPPH method, the test material was mixed with 3ml of DPPH solution and kept in the dark for 30 minutes. The DPPH solution without a sample was used as control and methanol as blank. Absorbance was measured using a spectrophotometer at 515 nm. Antioxidance (%) = (Absorbance of control – Absorbance of sample)/(Absorbance of control) × 100

In the ABTS method, the ABTS solution without a sample was used as a control. PBS was used as blank. Absorbance at 734 nm was measured using a spectrophotometer.

Antioxidant ability (%) = (Absorbance of control – Absorbance of sample)/(Absorbance of control) × 100

Enzyme inhibition assay

An inhibition assay was carried out utilizing the DNS method. The complete assay mixture consisted of 200 µl of a 0.02 M sodium phosphate buffer, 1ml of amylase and extracts of concentration ranging from 20-100 µl were incubated at 37°C for 10 minutes. 200 µl of preincubated 1% starch solution was added to each tube and incubated at 37 °C for 15 minutes. The reaction was halted by introducing 400 µl of DNS reagent, followed by incubation in a water bath for 5 minutes. After cooling to room temperature, it was further diluted with 15 µl of distilled water, and the absorbance was subsequently measured at 540 nm. Inhibition ability (%) = (A540 of control – A540 of sample)/(A540 of control) × 100





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Metabolite profiling using GC – MS

An Agilent 6890 gas chromatograph was equipped with a straight deactivated 2 mm direct injector liner and a 15m Alltech EC-5 column (250µ I.D., 0.25µ film thickness). Sample introduction utilized a split injection, with a split ratio set at 10:1. The oven temperature program was initiated at 350°C, held for 2 minutes, and then increased at a rate of 20°C per minute until it reached 300°C, where it was maintained for 5 minutes. The helium carrier gas was set to a constant flow mode at a rate of 2 ml/minute. For analysis, a JEOL GCmate II benchtop double-focusing magnetic sector mass spectrometer operated in electron ionization (EI) mode, utilizing TSS-2000 1 software. Low-resolution mass spectra were captured at a resolving power of 1000 (20% height definition), scanning the range from m/z 25 to m/z 700 at 0.3 seconds per scan with a 0.2-second inter-scan delay. High-resolution mass spectra were recorded at a resolving power of 5000 (20% height definition), scanning from m/z 65 to m/z 750 at 1 second per scan. The identification of the purified compound involved comparing their recorded spectra with the mass spectra data stored in the NIST library V 11 provided by the instrument's software.

Anticancer activity by MTT assay

SIHA cells (5,000 cells per well) were cultured in 100 mL of Dulbecco's Modified Eagle's Medium (DMEM) for 24 hours. Afterward, 100 mL of active extracts with concentrations of 5 µg/mL, 25 µg/mL, 125 µg/mL, and 625 µg/mL were added to the cell culture and incubated in a CO₂ incubator at 37°C for an additional 24 hours. Following the incubation, 100 µL of MTT (3-[4,5-dimethylthiazol-2-yl] 2,5-diphenyltetrazolium bromide) was introduced into each well and incubated for 4 hours at 37°C. Subsequently, the absorbance of formazan was measured at a wavelength of 595 nm. The percentage inhibition of SIHA cells was determined using the following formula:

Percentage Inhibition (%) = [(Absorbance of Control - Absorbance of Extract) / Absorbance of Control] × 100

Where:

- Absorbance of Control refers to the absorbance of cells without the extract.
- Absorbance of Extract is the absorbance of cells treated with the extract at various concentrations.

RESULTS AND DISCUSSION**Morphological Identification**

Exiguobacterium profundum (*E. profundum*), with GenBank Accession No. OR262688, is a bacterium belonging to the Gram-positive category. It is characterized as halotolerant, meaning it can withstand relatively high salt concentrations, and it is a facultative anaerobe, implying that it can thrive in both oxygen-rich and oxygen-depleted environments. *E. profundum* is moderately thermophilic, showing a preference for moderate temperatures. It does not form spores. This bacterium is a member of the *Exiguobacterium* genus and was originally isolated from marine crustaceans, specifically *Portunus pelagicus* (*P. pelagicus*) intestinal gut as represented in Fig. 1.

Biochemical identification

The biochemical characterization of secondary metabolite was performed using the standard procedure as given in Table 1. In terms of biochemical identification, *E. profundum* tested positive for various assays, including the citrate utilization test, urease test, triple sugar iron test, and sugar fermentation test. The biochemical test results also reveal the crucial role of (*E. profundum*) in industrial biotechnology. This bacterium is also salinity tolerant and can also be employed as a biosurfactant agent (Al-Ani et al., 2022).

Molecular identification – PCR

To extract genomic DNA, overnight cultures of the selected bacterial isolates were utilized, and a QIAGEN DNA isolation kit was employed. The extracted DNA was suspended in 100 µL of elution buffer (10 mM/L Tris-HCl, pH 8.5) and its concentration was quantified by measuring the optical density (OD) at 260 nm. PCR amplification was conducted using a 50 µL reaction mixture, which included 100 ng of template DNA, 20 µmol of 16S rRNA primers, 200 µM of deoxyribonucleotide triphosphates (dNTPs), 1.5 mM of MgCl₂, 1 unit of Taq DNA polymerase (MBI Fermentas), and 10 µL of 10x Taq polymerase buffer. The 16S rRNA primer sequences used were as follows:



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- 27f: (5'-AGAGTTTGATCCTGGCTCAG-3')
- 1522r: (5'-AAGGAGGTGATCCANCCRCA-3')

The PCR process consisted of an initial denaturation at 95°C for 5 minutes, followed by 35 cycles of denaturation at 94°C for 45 seconds, annealing at 56°C for 45 seconds, extension at 72°C for 1 minute, and a final extension step at 72°C for 5 minutes. This PCR was performed using a thermocycler (iCycler; Bio-Rad Laboratories, CA).

The resulting PCR products were then analyzed by electrophoresis on a 1% agarose gel in 1x Tris-Borate-EDTA (TBE) buffer at 100 volts. Subsequently, the amplified DNA product was sequenced using an ABI PRISM 3730 Genetic Analyzer (Applied Biosystems), as depicted in Figure 2. The molecular profiling of *E. profundum* MKJCBT23 also unveils their importance in understanding the pathways associated with predicting the osmotic stress, differential temperature and their capability of degrading heavy metals present in marine water (Patel, V. K et al., 2018)

Phylogenetic analysis

The sequences of the 16S rRNA genes were compared to sequences available in GenBank, specifically Accession No. OR262688, using the BLASTN program (Altschule *et al.*, 1990). Subsequently, the sequences were aligned using CLUSTAL W software (Thompson *et al.*, 1994). Distances between sequences were computed utilizing Kimura's two-parameter correction (Kimura, 1980). To create phylogenetic trees, the neighbour-joining method was employed (Saitou and Nei, 1987). To assess the robustness of the tree, bootstrap analysis was conducted with 1000 replications. The MEGA4 package (Kumar *et al.*, 2007) was used for all analyses.

Sequences of the sample

>MKJCBT23

```
CCGGTTCGTCCTCATATACTGCAAGTCGAGCGCAGGAAGCCGTCTGAACCCCTTCGGGGGACGACGGTGGA
ATGAGCGGCGGACGGGTGAGTAACACGTAAAGAACCTGCCCATAGGTCTGGGATAACCACGAGAAATCGG
GGCTAATACCGGATGTGTTCATCGGACCGCATGGTCCGCTGATGAAAGGCGCTCCGGCGTCGCCCATGGATGG
CTTTGCGGTGCATTAGCTAGTTGGTGGGGTAACGGCCCAACCAAGGCGACGATGCATAGCCGACCTGAGAGG
GTGATCGGCCACACTGGGACTGAGACACGGCCCACTCCTACGGGAGGCAGCAGTAGGGAATCTTCCACA
ATGGACGAAAGTCTGATGGAGCAACGCCGCGTGAACGATGAAGGCTTCGGGTCGTAAAGTTCTGTTGTAA
GGGAAGAACAAAGTCCCGCAGGCAATGGCGGCACCTTGACGGTACCTTGCGAGAAAGCCACGGCTAACTAC
GTGCCAGCAGCCGCGGTAATACGTAGGTGGCAAGCGTTGTCCGGAATTATTGGGCGTAAAGCGCGCGCAGG
CGGCCTCTTAAGTCTGATGTGAAAGCCCCGGCTCAACCGGGGAGGGCCATTGGAACTGGGAGGCTTGAG
TATAGGAGAGAAGAGTGGAATTCACGTGTAGCGGTGAAATGCGTAGAGATGTGGAGGAACACCAGTGGC
GAAGGCGACTCTTTGGCCTATACTGACGCTGAGGCGCGAAAGCGTGGGGAGCAACAGGATTAGATACCC
TGGTAGTCCACGCCGTAAACGATGAGTGCTAGGTGTTGGAGGGTTCCGCCCTTCAGTGCTGAAGCTAACGC
ATTAAGCACTCCGCCTGGGGAGTACGGTCGCAAGGCTGAAACTCAAAGGAATTGACGGGGACCCGCACAA
GCGGTGGAGCATGTGGTTTAATTCGAAGCAACGCGAGAACCTTACAACCTTTGACATCCTCTGACGGTACA
GAGATGT
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The evolutionary history was deduced through the application of the Neighbor-Joining method (Saitou and Nei, 1987). The optimal tree, with a sum of branch length equal to 0.00571483, is presented. The percentage of replicate trees in which the associated taxa clustered together during the bootstrap test (conducted with 1000 replicates) is indicated adjacent to the branches (Felsenstein, 1985). The tree has been scaled to represent branch lengths in the same units as the evolutionary distances used to construct the phylogenetic tree. These evolutionary distances were calculated using the Kimura 2-parameter method, (Kimura, 1980) and are expressed in the units of the number of base substitutions per site. The codon positions considered in this analysis encompassed 1st, 2nd, 3rd, and noncoding positions. Any positions containing alignment gaps and missing data were exclusively removed in pair wise sequence comparisons, adhering to the pairwise deletion option. The final dataset consisted of a total of 1461 positions. These phylogenetic analyses were carried out using MEGA4 (Tamura *et al.*, 2007). Based on the BLAST analysis conducted in the NCBI, RDB taxonomy analysis, and the resulting phylogenetic tree, it was clearly



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established that the sample in question belongs to the actinomycetes group, with its taxonomic classification being *E. profundum*, as illustrated in Figure 3.

Microbiological Analysis and isolation of bacterial colony

Several colonies with distinct characteristics, such as creamy or white in color, were initially selected and purified from marine nutrient agar. During the preliminary antibacterial activity evaluation, among the 75 isolates tested, only five exhibited inhibitory zones, the extracts of the isolates from black crab 1, sea crab 1-1, and scar crab 1 showed good activity against indicator pathogen *Bacillus subtilis* (*B. subtilis*). The result also emphasizes their ability to sustain in hard environments due to high adaptable physiology (White III et al., 2019).

Antagonistic activity of bacteria and fungi

Among the five isolates, the isolate (sea crab strain 2) which has shown high antibacterial activity against *B. subtilis* shown in Table 2, was raised in broth culture for further assays. The experimental result suggests that intestinal bacteria with antibacterial properties might inhibit the growth of invading bacteria in the intestines of crustaceans. The strains have not shown any zone of inhibition for fungi against *Aspergillus niger* and *Aspergillus fumigates*. All the microorganisms were gifted by Apex Laboratory, Chennai. The earlier research explored the antibacterial properties of crustacean shells but not the gut bacterial extract. As reported (Laith A A., 2017), antibacterial activity was performed using hemolymph, whole crab extract, and shells. The experiment assessed revealed that *P. pelagicus* contains a rich source of antibacterial agents. The present study attempted to explore the antibacterial activity of intestinal gut bacterial flora in a variety of crabs among which *P. pelagicus* has produced a significant antagonistic activity. This may be the first study that utilized metabolite extracted from the gut. They can also be utilized in pharmaceutical industries as drug agents. This indicates that strains can be employed as potent antibacterial agents.

Free radical scavenging activity

The free radical scavenging activity was performed to analyze the scavenging property of the strain by two different methods such as ABTS and DPPH assay. It is the fundamental screening method to know the antioxidant capacity of the strain *P. pelagicus*, because antioxidant property reveals various potential such as anti-aging, antitumor, cell damage and antimutagenicity (N.C. Cook & S. Samman 1996). As shown in Table 3 and Figure 4. Free radical scavenging activity of strain against radical ABTS has produced maximum scavenging of about 83.57% at the concentration of 100 µg/µl. The free radical scavenging property of the strain was also analyzed by the DPPH method, where the strain has produced about 41.77% antioxidant ability at the concentration of 100 µg/µl as given in Table 4 and Figure 5. The results reveal that antioxidant ability increases with an increase in concentration. A significant difference in results is due to the type of free radicals, their binding affinity, type of bioactive compound present in the extract some of the bioactive compounds may react at a very low level and the antioxidant reactions are also a time-consuming process.

Enzyme inhibition assay

The alpha amylase inhibition assay has a crucial role in the management of diabetes and it also has several health benefits. This research might be a new approach to utilizing the gut bacterial flora of *P. pelagicus*. As in Table 5, the results show a concentration-dependent inhibition activity of 65.90% inhibition at the concentration of 100 µg/µl which is also evidenced in Figure 6. The experiment also confesses the benefits of intestinal gut bacteria, which can be employed in pharmaceutical industries.

Metabolite profiling using GC – MS

Seven major secondary metabolites confirmed the presence of carotenoids, esters, corticosterone and phenolic compounds at the retention time ranged from 15.13 to 19.87. Metabolite profiling of *Protunus pelagicus* confirmed the presence of fatty acids, stearic acid and esters as listed in table 6 and peak area with retention given in Figure 7.





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Anticancer activity by MTT assay

The anticancer activity of marine bacterial isolate was tested against SIHA cells using an MTT assay. The absorbance of formazan was measured in an ELISA reader at 595 nm wavelength. The percentage inhibition of SIHA cells (viability) is given in Figure 8. Activity minimum inhibition of about 49 % viability at the concentration of 150 $\mu\text{g}/\mu\text{l}$. This confirms that the marine gut bacterial isolate can be utilized as an effective chemotherapeutic drug.

Conclusion

There are oceans of unexplored novel bioactive secondary metabolites present in marine crustaceans. Marine crustaceans are rich sources of protein and feed millions of populations. Meanwhile, the marine intestinal guts, shells, and scales are disposed of into the environment. In lieu of dumping as waste, these can be transformed into a value-added bioproduct. Among five varieties of crabs, the secondary metabolite isolated from *P. pelagicus* proved to be effective and robust antagonistic activity evidenced through free radical scavenging, which can be employed as a chemotherapeutic drug. The Bay of Bengal represents a promising reservoir of biologically active actinomycetes, which possess the capability to generate novel and potent secondary metabolites with antimicrobial properties. As depicted in Figure 9, the bioprospecting of these isolates has uncovered fresh possibilities and strategies, holding significant potential in various industries, including pharmaceuticals, nutritional supplements, cosmetics, agrichemicals, and enzymes. Each of these marine bioproducts carries substantial market value, offering exciting opportunities for commercial application.

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Table 1 Biochemical characterization of secondary metabolite extract

S.No.	TESTS	RESULTS
1.	Citrate utilization test	Positive
2.	Urease test	Positive
3.	Triple sugar iron test	Yellow slant + yellow butt
4.	Indole test	Negative
5.	Voges proskauer test	Negative
6.	Catalase test	Negative
7.	Oxidase test	Negative
8.	Sugar fermentation test	Positive

Table 2. Antagonistic activity of bacteria and fungi

S.No.	SAMPLE EXTRACTS	CONCENTRATION AND ZONE OF INHIBITION	
		50 μ l	100 μ l
1.	<i>Scylla tranquebarica</i> strain 1	14mm	20mm
2.	<i>Scylla olivacea</i> strain 1	18mm	23mm
3.	<i>Scylla olivacea</i> strain 2	20mm	21 mm
4.	<i>P. pelagicus</i> strain 2	25mm	30mm
5.	<i>Portunussanguinolentus</i> strain 1	20mm	23mm

Table 3 Free radical scavenging activity of the strain *P. pelagicus*

S.No.	CONCENTRATION (μ g/ μ l)	OD AT 734 NM	ABILITY (%)
1.	20	0.204	70.86%
2.	40	0.132	81.14%
3.	60	0.125	82.24%
4.	80	0.121	82.71%
5.	100	0.115	83.57%

Table 4. In the DPPH free radical scavenging method

S.No.	CONCENTRATION (μ g/ μ l)	OD AT 515 nm	ABILITY (%)
1.	20	0.471	24.03%
2.	40	0.462	25.48%
3.	60	0.402	35.11%
4.	80	0.385	37.90%
5.	100	0.361	41.77%





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Table 5. The alpha – amylase inhibition assay

S.No.	CONCENTRATION (µg/µl)	OD AT 540 NM	INHIBITION (%)
1.	20	0.022	50%
2.	40	0.019	56.81%
3.	60	0.018	59.09%
4.	80	0.016	63.63%
5.	100	0.015	65.90%

Table 6. Metabolite profiling of *P. pelagicus* using GC – MS

Peak No.	RT (Min.)	Compound Name	Peak Area	Peak Area (%)
1.	15.13	9-Methylcortocosterone acetate	1251421	3.43
2.	15.9	3-O-Methyl-d-glucose	2425142	6.64
3.	16.9	Estra-1,3,5[10]-trien-17 a-ol	4572142	12.52
4.	17.12	Methyl 9,12-epithiostearate	1254253	3.43
5.	17.68	Benzene, 1,4-bis[1-methylethyl]	24521425	67.15
6.	18.7	9-Methylcortocosterone acetate	1251423	3.43
7.	19.87	Corynan-17-ol, 18,19-didehydro-10-methoxy-, acetate [ester]	1241253	3.40
		Total	36517059	100.00

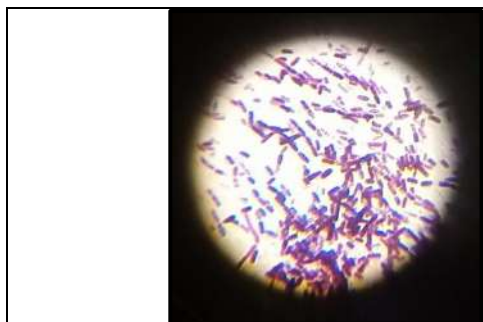
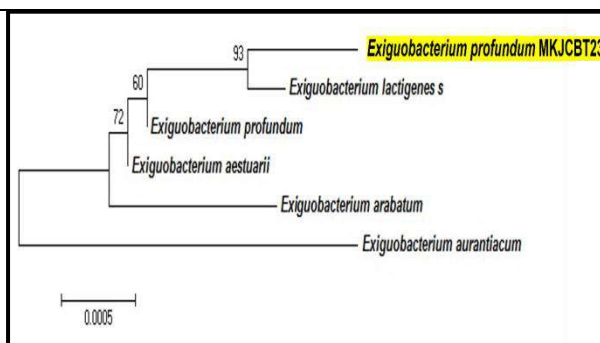
Fig.1 Gram Staining of *Exiguobacterium profundum*

Fig. 2 Phylogenetic Tree Analysis

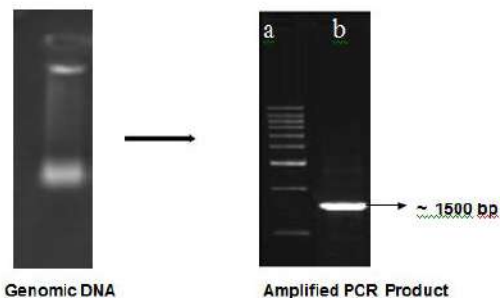


Fig. 3 PCR amplification of the isolated bacterial colony, in this (a) represents the 1KB DNA marker ladder and (b) represents the amplified genomic DNA that is approximately 1500bp

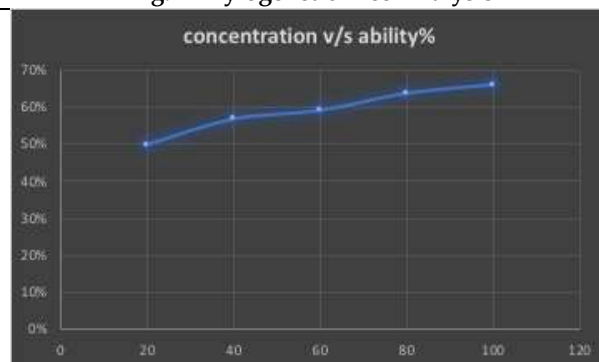


Fig. 4 Free radical scavenging property of isolate analyzed by ABTS method





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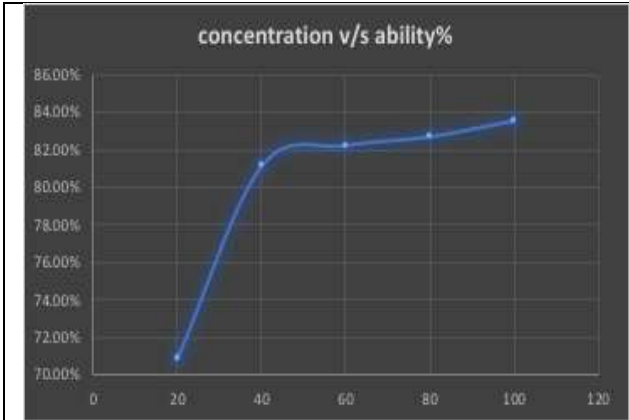


Fig. 5 Free radical scavenging property of isolate analyzed by DPPH method

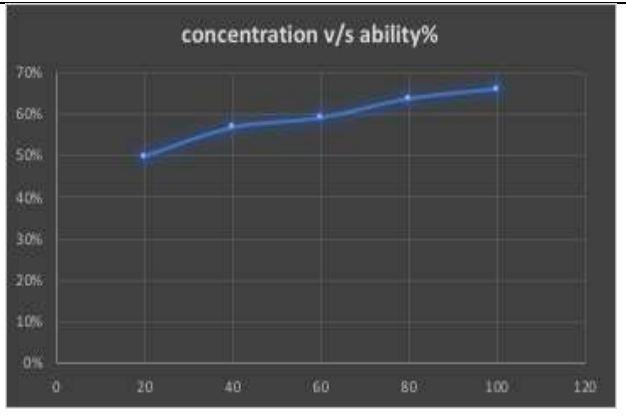


Fig. 6 Alpha amylase inhibition property of marine crustacean isolate

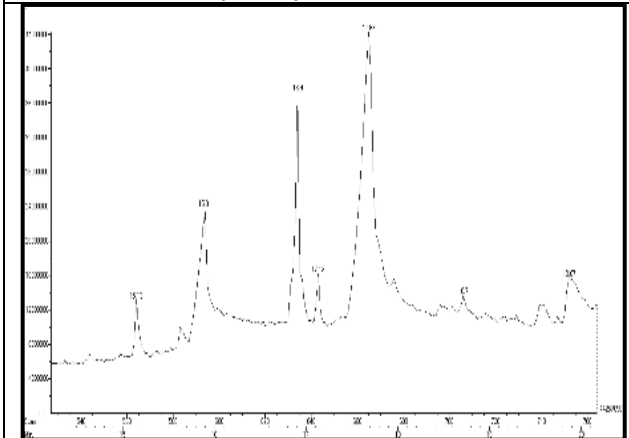


Fig. 7 Metabolite profiling using GC – MS, based on peak value and retention time functionally active compounds has been identified

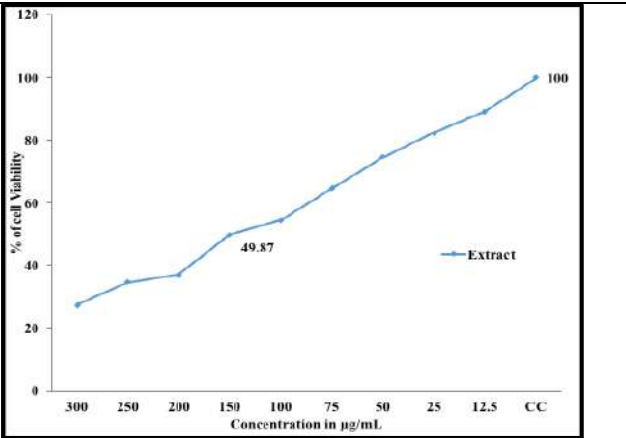


Fig. 8 Anticancer activity of secondary metabolite extracted from *P. pelagicus*





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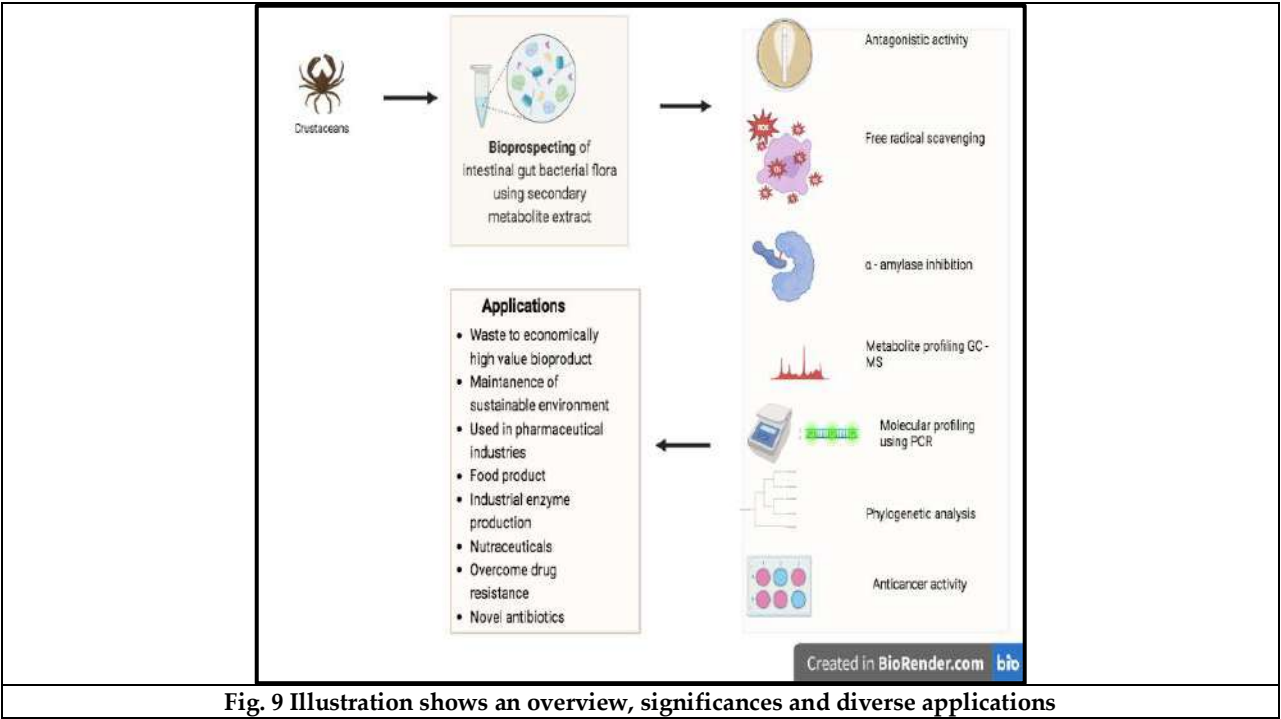


Fig. 9 Illustration shows an overview, significances and diverse applications





Toxicity Study of Red Marine Algae *Gracilaria salicornia* (C. Agardh) from the Tamil Nadu Coastal Ecosystem against the Rice Leaf Folder, *Cnaphalocrocis medinalis* (Guenee)

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ABSTRACT

This study explores the bio-efficacy and pesticidal potentials of various seaweed extracts, focusing on their impact against significant agricultural pests, including *Spodoptera litura*, *Dysdercus cingulatus*, and *Cnaphalocrocis medinalis*. Marine macroalgae, particularly red, brown, and green seaweeds, exhibit promising insecticidal, repellent, and growth-regulating properties due to their diverse bioactive compounds. Extracts from species such as *Gracilaria firma*, *Caulerpa scalpelliformis*, *Sargassum tenerrimum*, and *Ulva lactuca* were assessed for their pesticidal potential. Additionally, the role of abiotic factors in pest incidence and the behavioral impacts of Neem based biopesticide were investigated. Results demonstrate significant toxicity, growth inhibition, and behavioral alterations in target pests, indicating the potential of these seaweed-based biopesticides as eco-friendly alternatives for sustainable pest management. This study highlights the critical need for integrating marine-derived bioactive compounds into agricultural practices to reduce reliance on synthetic chemicals and enhance crop productivity.

Keywords: Marine algae, *Gracilaria salicornia*, Rice leaf folder (*Cnaphalocrocis medinalis*), Bio-efficacy and Seaweed extracts.





INTRODUCTION

Rice (*Oryza sativa* L.) is the main staple food for 2/3rd (almost two – third) of the world's population. Rice is rich in CHO (90%), starch (80-90%), protein (8%) and low in fat (2%) (Verma et al., 2011). Rice is prone to the attack of many insect pests, from sowing to harvest (Mandal and Mondal, 2018). Among those pests, Rice Leaf folder, *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae) is a major and destructive pest in rice ecosystem. They yield loss due to the infestation by rice leaf folder ranges between 5 and 25 per cent and it attacks the plant from tillering to booting stage (Kulgagod et al., 2011). Currently, the rice leaf folder population is predominantly controlled with chemical insecticides. However, repeated application of insecticides to control the pest population leads to insecticide resistance with resurging pest populations each year (Senthilnathan, 2011). Shyamrao and Raghuraman (2019) also stated that rice leaf folder turned to a major pest during the last two decades due to the indiscriminate use of nitrogenous fertilizers. Hence, switching over to eco-friendly insect pest management is considered to be a better alternative to insecticide usage. Among the different alternatives, seaweeds offer a non-toxic way to manage the pests (Hamed et al., 2018). Marine algae as renewable living resources are rich in biologically active metabolites and possess many insecticidal activities (Sahayaraj and Jeeva, 2012). *Gracilaria salicornia* is a red algal seaweed that occurs in the coastal area. This species was distinguished by its articulated branches and a characteristic yellow to orange color. In this context, our research was aimed at estimating the efficacy of a red algal seaweed *Gracilaria salicornia* (C. Agardh) for their insecticidal activity against the Rice Leaf folder (*Cnaphalocrocis medinalis*).

MATERIALS AND METHODS

Collection of seaweed

The seaweed belonging to the Rhodophyta, Red algae *G. Salicornia* were collected from the intertidal region and deep-sea regions of Mandapam, Ramanathapuram District, Tamil Nadu, Southeast coast of India by hand picking. Aqua Agri Processing Private Limited aided in the handpicking, dredging, and scuba diving. The collected seaweed sample was washed with seawater then transferred to the lab and washed with distilled water till the debris, related biota was eliminated. The sample was eventually shade – dried for three weeks and saved in air – tight bags (Kannan and Bharath Kumar, 2016). The collected seaweeds have been preserved and identified by Dr. P. Ananda Raman, Professor in Marine Biology and Centre for Advanced Studies in Marine Biology, Faculty of Marine Sciences, Annamalai University.

Mass culture of test insect

Rice cultivar (TN1) collected from Tamil Nadu Rice Research Station (TRRI-TNAU), Aaduthurai, Thanjavur district was used for the assessment of *Gracilaria Salicornia* against the rice leaf folder. TN1 seedlings were raised in cement pots for one month and maintained in cement pots covered with nylon mesh sleeves at temperature 26° to 28°C with a relative humidity of 80 per cent. Irrigation was done at regular intervals. The initial culture was established with the release of field collected larvae (Annamalainagar, Vallambadugai, Bhuvanagiri) into the potted rice plants in the greenhouse. The larvae were fed with leaves up to pupation. After pupation, emerged adults were collected and released into ovipositional cage (120 × 80 × 50 cm) containing rice plants. The culture was maintained with 12 females and 13 male moths inside the cages. Adult moths were provided with 10 per cent honey solution as food and allowed for laying eggs. After two days, the leaves containing eggs were clipped off from the plants and kept in the Petri plate with moist filter paper to keep the leaves fresh and maintain the moisture. The emerged larva was reared up to the third instar in rice plants grown inside the greenhouse and these larvae were used for experiments in Laboratory (Senthilnathan, 2005).





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Preparation of seaweed

The red seaweed *G. salicornia* was tested on rice leaf folder *C. medinalis* in different formulations such as powder, aqueous solution and solvent extract. The dried plant materials were converted into a fine powder with the help of an electric blender. This fine powder was stored in a glass container and used for further experiments. A known concentration of powder formulation (2g,4g,6g,8g,10g) was topically applied on the test insect (Kannan and Bharath Kumar, 2016). For aqueous extract, 100g powdered seaweed was taken and mixed with 100ml water and kept overnight. This solution was filtered with fine muslin cloth and made up to different concentrations (1%,2%,3%,5%,10%) (Gunalan, 2019). Similarly for solvent extract, powdered *G. salicornia* was individually weighed as 1, 2, 3, 5 and 10g and mixed in 100ml solvent (acetone) separately and incubated for 12 hours at room temperature and filtered. The filtered extracts were stored in an amber color bottle at 4°C in a refrigerator and used for bioassay experiments (Kombiah and Sahayaraj, 2012).

Bioassay –No choice method:

TN1 variety of rice plants (5 cm) was treated with Tween 20 (1% - to remove wax layer) and were placed in a Petri plate @ five –leaf bits/dish and the leaves were dusted with seaweed powder at different concentrations, in case of aqueous/ solvent the leaf bits were dipped in different concentration and their effects were compared with a standard check (Neem leaf powder/ extract – 5%) and untreated control under Completely Randomized Design with three replications. Three hours pre – starved third instar larvae were released at the rate of 5 larva/ per Petri plate and allowed to feed on the treated rice leaves. After subsequent feeding, larvae were provided with untreated leaves for continuous observations. The insect mortality and IGR activity (during larval, pupal, and adult stages) data were recorded every 6 hours on the test insect till adult emergence. Observations were made on the growth of the test insect analyzed statistically.

RESULT AND DISCUSSION**Effect of *G. salicornia* extract on growth and development of *C. medinalis***

In this Investigation, the effect of different extracts of red algal sea weed extract on larvicidal and insect growth regulator activity on *C. medinalis* brought out the following findings. The observed larval mortality was observed from the initial period onwards i.e., six hours after treatment, T₅ (10%) of all the experiment expels 6.67 per cent mortality each wherein other treatments including standard check and untreated control exhibited no larval mortality. The influence of seaweed effect on the test insect gradually increased thereafter and at 12 and 18 hours of exposure, the highest mortality was observed in higher dosage T₅ @ 33.33 in acetone extract followed by powder with 26.67 then aqueous with 20 per cent wherein no casualty was recorded in the untreated control (T₇) without statistical significance in larval mortality between the treatments and controls. Eventually, the data ascertained after 24 hours of treatment revealed the larval mortality by all the treatments and standard checks wherein the range of mortality was within 13.33 to 46.67 in acetone extract was preferably higher than the powder and aqueous extract where higher concentration exerted 40 and 33.33 per cent. A similar trend of gradual increase in larval mortality in all the treatments was noticed at 36, 48, 60 and 72 hours after exposure. The larval mortality increased further in all the experiments as evidenced from the data obtained from 48 hours of the treatment shows increase in the level of mortality from the lower (1%) to higher concentration (10%) were acetone extracts exhibited more than 60 per cent of death rate on comparison with powder and aqueous. The mortality of the test insect reached its peak within 72 hours of the treatment where the maximum mortality was obtained from a 10 per cent concentration of acetone extract where it shows more than 70 per cent casualty other concentration of acetone extract also showed more than 50 per cent of death rate followed by this the maximum concentration (10g) of powder shows 66.67 per cent then aqueous extract (10%) shows 60 per cent which were comparatively higher compared to standard check where casualty maximum noticed in acetone extract (53.33%) whereas the other seaweed treatments have registered lesser mortality rate with significant difference between treatments and controls, wherein untreated control did not encounter any level of mortality.



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Those survived larvae were transformed to pupa. The observation period extended up to the adult emergence where in the pre – pupal mortality was also noticed under the higher concentration prominently and vice – versa in a lower concentration. The pupation per centage was calculated based on the insect population that survived and the observation data denoted that the highest pupation rate occurs in the aqueous extract of seaweed with 93.37 per cent (1%) on other hand, least pupation rate occurred in powder form with 13.33 per cent (10g) and 100 per cent occurred in control in all the experiment as usual. The pupated insects were observed for adult emergence, meanwhile, the effect of seaweed greatly influenced the pupal stage and resulted in pupal malformation in due course of the observation period where a higher concentration (10%) of the all the bioassay significantly shows malformed pupae. Other pupae were emerged out a healthy adult and the data showed the least no of adult emerged @ 10 per cent of acetone extract and in powder form with 13.33 per cent where aqueous shows 26.67 per cent and the maximum no. of adults emerged out in control (100%) compared with other lower dosage and standard check. Adultmal formation was also noticed in higher dosages of 5, 10 per cent of a solvent extract with a significant difference which indicated a substantial difference between treatments with no mortality in the control. Among the three experiments of seaweed, solvent (acetone) extract expels the maximum efficacy on test insect compared with the powder and aqueous extract in all forms. The results also confirmed the presence of toxic principles in the selected red algal seaweeds which demonstrated larvicidal and growth regulator activity of *C. medinalis*.

These defined results from the above experiments are in close proximity to the the results observed by the other researchers around the globe and their views are disclosed as given below. Kalimuthu *et al.* (2014) demonstrated the bio-efficacy and potential of *Gracilaria firmain* different solvent extracts in combination with *Megacyclops formosanus* for controlling the larvae of *Aedes aegypti*. Mortality was observed from the 24 hours of the treatment where the first in star larvae showed casualty up to 48 per cent in methanol extract of *G. firma* treatment at 0.251 per cent dosage, wherein at 1 per cent of dosage exhibited 100 per cent mortality was registered. Moustafa *et al.* (2014) reported that the various solvent extracts of green algae *U. lactuca* tested on larval growth of *S. littoralis* reported that it expels higher mortality, highest inhibition of pupation and adult malformation. Out of these, acetone extract of seaweed reported more efficacy against *Culex pipens*. Investigations on the powder of red algal seaweeds against *Spodoptera litura* revealed that *Gracilaria corticata* exhibited cent per cent larval mortality followed by *Asparagopsis taxiformis* and *Liagora ceranoides* which reported more than 50 per cent mortality and recorded better insect growth regulator activity in *S. litura* test insect respectively (Dharanipriya *et al.*, 2019). Investigations on the pesticidal potential of several selected red algal seaweeds viz., *Gracilaria edulis*, *G. folifera*, *Grateloupia lithophila* and *Hypnea valentiae* methanol extracts against *S. litura* revealed that *G. edulis* recorded the maximum larval mortality and proved that the highest dosage of *G. edulis* exhibited desirable per centage of mortality and effect of insect growth regulatory activity (Gowthish and Kannan, 2019). The insecticidal properties of hexane, acetone and methanol extracts of *Gnidia kraussiana* Meisn roots and neem seed oil were tested against the eggs and larvae of different immature stages of *Callosobruchus maculatus*. The reports by Kosini *et al.* (2021) confirmed that acetone extracts were more effective against the immature stages of *C. maculatus*, as the extracts evoked stronger repellency and could be incorporated in integrated pest management programs for the control of *C. maculatus* in stored cowpea seeds. Furthermore, studies should be done with different kinds of solvents other than acetone under different increased concentrations.. In addition to this, it should be tested on the other leaf feeders to check their toxicity level and combination with neem oil, pungam oil, etc.

CONCLUSION

This study demonstrated the insecticidal potential of *Gracilaria salicornia*, a red algal seaweed, against the rice leaf folder, *Cnaphalocrocis medinalis*. Among the tested formulations, the acetone extract exhibited the highest efficacy, achieving significant larval mortality, pupal malformation, and inhibition of adult emergence, particularly at higher concentrations. The powder and aqueous formulations, while effective, were comparatively less potent. The findings confirm the presence of bioactive compounds in *G. salicornia* with larvicidal and insect growth regulatory properties. The study aligns with previous research on the pesticidal potential of algal extracts, reinforcing the suitability of





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seaweed-based biopesticides as eco-friendly alternatives to chemical insecticides. However, to broaden the scope of applicability, further studies should evaluate the efficacy of *G. salicornia* in other solvent systems, higher concentrations, and combinations with neem or pungam oil. Additionally, testing its effects on other rice pests could help integrate this biopesticide into sustainable pest management programs. The use of *Gracilaria salicornia* as a natural pesticide represents a promising approach to reducing the reliance on synthetic chemicals, minimizing environmental impact, and combating issues like pesticide resistance and pest resurgence.

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Table.1: Larvicidal effect of *G. salicornia* powder on *C. medinalis*

TREATMENT	% LARVAL MORTALITY AFTER		
	24h	48h	72h
T ₁ <i>G. salicornia</i> (2g)	6.67 ^d (8.85)	6.67 ^e (8.85)	13.33 ^f (17.70)
T ₂ <i>G. salicornia</i> (4g)	6.67 ^d (8.85)	20.00 ^d (21.92)	26.67 ^e (30.77)
T ₃ <i>G. salicornia</i> (6g)	20.00 ^c (21.92)	33.33 ^{bc} (34.99)	33.33 ^d (34.99)
T ₄ <i>G. salicornia</i> (8g)	33.33 ^b (34.99)	40.00 ^b (39.21)	53.33 ^b (46.90)
T ₅ <i>G. salicornia</i> (10g)	40.00 ^a (39.21)	53.33 ^a (46.90)	66.67 ^a (54.96)
T ₆ Neem leaf powder (5g)	20.00 ^c (21.92)	33.33 ^{bc} (34.99)	46.67 ^c (43.06)
T ₇ Untreated control	0.00 ^e (0.00)	0.00 ^f (0.00)	0.00 ^g (0.00)
SEd	2.39	2.82	3.03
CD(p=0.05)	5.16	6.09	6.54

Values are mean of three replicates; values enclosed in parentheses are arc sine transformed values; Means followed by common alphabet are not significantly different at 5% level by LSD.

Table.2: Larvicidal effect of *G. salicornia* aqueous extract on *C. medinalis*

TREATMENT	% LARVAL MORTALITY AFTER		
	24h	48h	72h
T ₁ <i>G. salicornia</i> (1%)	0.00 ^e (0.00)	0.00 ^e (0.00)	6.67 ^f (8.85)
T ₂ <i>G. salicornia</i> (2%)	6.67 ^{cd} (8.85)	13.33 ^d (17.70)	26.67 ^e (30.77)
T ₃ <i>G. salicornia</i> (3%)	13.33 ^c (17.70)	26.67 ^{abc} (30.77)	33.33 ^d (34.99)
T ₄ <i>G. salicornia</i> (5%)	20.00 ^b (21.92)	33.33 ^{ab} (34.99)	46.67 ^b (46.90)
T ₅ <i>G. salicornia</i> (10%)	33.33 ^a (34.99)	53.33 ^a (46.90)	60.00 ^a (51.12)
T ₆ Neem leaf extract (5%)	6.67 ^{cd} (8.85)	26.67 ^{abc} (30.77)	40.00 ^c (39.21)
T ₇ Untreated control	0.00 ^e (0.00)	0.00 ^e (0.00)	0.00 ^g (0.00)
SEd	2.55	3.45	2.81
CD (p= 0.05)	5.52	7.46	6.08





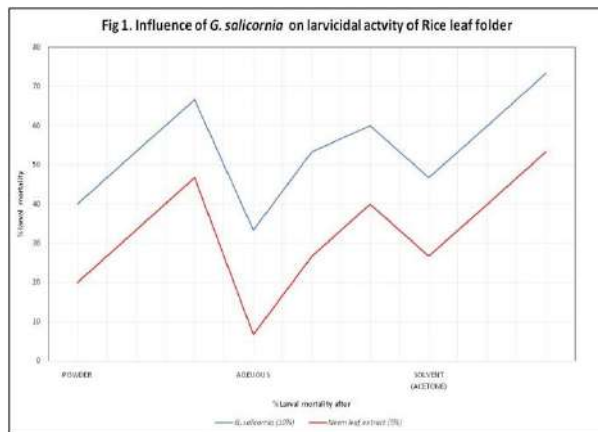
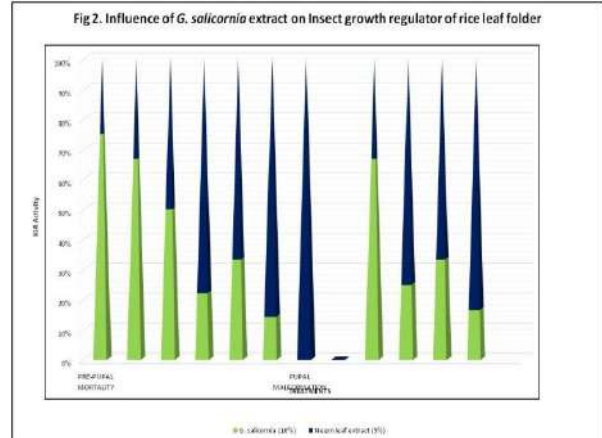
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Values are mean of three replicates; values enclosed in parentheses are arc sine transformed values; Means followed by common alphabet are not significantly different at 5% level by LSD.

Table.3: Larvicidal effect of *G. salicornia* acetone extract on *C. medinalis*

TREATMENT	% LARVAL MORTALITY AFTER		
	24h	48h	72h
T ₁ <i>G. salicornia</i> (1%)	13.33 ^e (17.70)	20.00 ^f (21.92)	26.67 ^f (30.77)
T ₂ <i>G. salicornia</i> (2%)	20.00 ^d (21.92)	33.33 ^e (34.99)	40.00 ^e (39.21)
T ₃ <i>G. salicornia</i> (3%)	26.67 ^{bc} (30.77)	46.67 ^c (43.06)	46.67 ^d (43.06)
T ₄ <i>G. salicornia</i> (5%)	33.33 ^b (34.99)	53.33 ^b (46.90)	60.00 ^b (51.12)
T ₅ <i>G. salicornia</i> (10%)	46.67 ^a (43.06)	60.00 ^a (51.12)	73.37 ^a (59.18)
T ₆ Solvent control (1%)	13.33 ^e (17.70)	13.33 ^g (17.70)	20.00 ^g (21.92)
T ₇ Neem leaf extract (5%)	26.67 ^{bc} (30.77)	40.00 ^d (39.21)	53.33 ^c (46.90)
T ₈ Untreated control	0.00 ^f (0.00)	0.00 ^h (0.00)	0.00 ^h (0.00)
SEd	2.97	2.01	2.44
CD (p=0.05)	6.42	4.35	5.28

Values are mean of three replicates; values enclosed in parentheses are arc sine transformed values; Means followed by common alphabet are not significantly different at 5% level by LSD

Figure.1: Influence of *G. salicornia* on larvicidal activity of Rice leaf folderFigure.2: Influence of *G. salicornia* extract on Insect growth regulator of rice leaf folder



RESEARCH ARTICLE

An Ethnobotanical Survey of Medicinal Plants in Marudhur Village, Karur District, Tamil Nadu, India

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ABSTRACT

An ethnobotanical survey was conducted in the Marudhur Village, Karur District, Tamil Nadu, India during January 2021 to May 2022 and the informations were collected from traditional healers, vaithiyars and age old people through questionnaire method. The proper knowledge reframed with the guidance of taxonomists and ethno botanists. From the present survey 63 plant species belongs to 32 families and 56 species dicotyledons and 7 species monocotyledons. In the Fabaceae is containing 7 species and *Azadirachta indica* A. Juss. (Neem.) is more species was available. This study explored the traditional knowledge about medicinal plants and their therapeutic applications from ancestors to future generations as well as the advantageous to prepare novel drug.

Keywords: Ethno botany, questionnaire, traditional knowledge, Survey and therapeutic applications



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INTRODUCTION

Ethno botany is the study of plants and their practical uses through the traditional knowledge of local people (Saran raj, 2016). Since the ancient period plants have been used for curing several ailments of mankind and animals. Population rise, inadequate supply of drugs, the prohibitive cost of treatments, side effects of several synthetic medications and development of resistance to currently used drugs for infectious diseases have led to increased emphasis on the use of plant material as a source of medicines for a wide variety of human ailments. Among ancient civilization, India has been known to be rich repository of medicinal plants. About 8000 herbal remedies have been codified in Ayush system in India. Ayurveda, Unani, Siddha and Folk medicines are the major systems of indigenous medicines knowledge (Gopal Dixit, 2019). Among these systems, Ayurveda and Unani medicine are most developed and widely practiced in India. Medicinal plant plays an important role in supporting healthcare system in world. According to the World Health Organization 80% of the rural population in developing countries utilizes locally available medicinal plants for their primary healthcare needs (Saran raj, 2016). According to WHO, around 21000 plant species have the potential for being used as medicinal plants. About 90% of the country's medicinal plants are found in forest habitats. It may be noted that India is one amongst those nations which possess a historical track record of having made a significant global contribution by virtue of its traditional knowledge of the medicinal plants.

MATERIALS AND METHODS

The Marudhur village is located at Kulithalai Taluk of Karur District, Tamil Nadu, India lies between 10°52'2" N and 78°26'48" longitude. The survey was conducted during January 2021 to May 2022 and the ethno botanical data were collected through questionnaire method (Anantgobalsingh *et al.*, 2012). The information about medicinal plants was collected from traditional healers age old people, vaidhiyars. The data was framed with the knowledge of taxonomists and ethno botanist. According to the Flora of the presidency of Madras (Gamble, 1915) medicinal plants were arranged. Some of the highly valuable medicinal plants are kept secret from ancient period to now by the traditional healers. The collected voucher specimens were deposited in the PG & Research Department of Botany, Vivekanandha College of Arts & Sciences for Women (Autonomous), Tiruchengode, Namakkal District and Tamil Nadu.

RESULTS

The traditional information was accumulated by the local people has play an important role. In the present study, medicinal plant used by the people of Marudhur Village were collected and recorded. From this, we find out the 63 plant species are comes under 56 dicotyledons and 7 monocotyledons are recorded. The different plant habitnatures are categorized, this study mostly exhibited herbs (26), Shrubs (20) and trees (17). The different medicinal uses of various plant parts are recorded (Figure -1). This present survey we identified 63 plant species belongs to 32 families such as Fabaceae (7 species) is the highest followed by Lamiaceae and Solanaceae (5 species), Euphorbiaceae (4 species), Moraceae (3 species), Acanthaceae, Annonaceae, Cucurbitaceae, Lythraceae, Myrtaceae, Phyllanthaceae, Rubiaceae, Rutaceae, Sapotaceae (2 species) and remaining families were single plant species present like Acoraceae, Amaranthaceae, Anacardiaceae, Arecaceae, Asphodelaceae, Asteraceae, Boraginaceae, Caricaceae, Cyperaceae, Malvaceae, Meliaceae, Musaceae, Oleaceae, Poaceae, Rhamnaceae, Sapindaceae, Simaroubaceae (Figure - 2) and as well as the study exposed many plant leaves and stems are used to cure the various diseases like fever, asthma, cough, cold, diarrhoea, rheumatism, ulcers, skin diseases, etc., (Figure-3). In the study area *Azadirachta indica* A. Juss. (Neem.) is highest population and *Adhatoda vasica* Nees. is least concern (Table 1 & Plate 1).





DISCUSSION

In this present study, we found that 63 medicinal plants belonging to 32 families were identified in the study area. In Worldwide many herbal medicines are prepared from different parts of the plants and they are cured many diseases through pharmacological analysis. Different plant species are used in the treatment such as anti - diabetic, hypertension, gastrointestinal diseases, respiratory diseases and haemorrhoids. Similarly, Natarajan *et al.*, (2012) documented that 80 medical plants belonging 41 families, 74 genera found in the Kalrayan hills, Tamil Nadu and Thangaraj Francis Xavier *et al.*, (2015) recorded 86 medicinal plants categorized under 46 families, 76 genera of Malayali tribes in Eastern Ghats, Tamil Nadu. Since they are also used in other parts of the world for treating comparable diseases, they can be considered as pharmacologically effective. Documentation of wild edible and medicinal plants from ethno botanical approach is important for enhancing understanding of indigenous knowledge systems. Therefore, this type of work may assist ethno botanical studies and also pharmaceutical leads to the formation of new drugs.

CONCLUSION

The traditional medicine is made up of different herbal formulations to cure many diseases and disorders. Due to the over consumption of medicinal plants, lack of population in certain area. So, there is urgent need for the scientific awareness about the importance of medicinal plants conservation and sustainable utilization of natural resources. Such ethno botanical studies enable the transfer of knowledge on plant-based treatments to be followed by the future generations.

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Table – 1: Medicinal uses of plant species of Mardhur Village, Karur

S. No	Botanical name	Tamil name	Family	Cotyledons	Habit	Parts used	Medicinal uses
1.	<i>Acalypha indica</i> L.	Kuppaimeni	Euphorbiaceae	Dicot	H	R, L & St	Anti- cancer, anti-ulcer, hepatitis, gout and anorexia
2.	<i>Achyranthes aspera</i> L.	Nayuruvi	Amaranthaceae	Dicot	H	WP	Anthelmintic, anti-bacterial and asthma
3.	<i>Acorus calamus</i> L.	Vasambu	Acoraceae	Monocot	H	R & L	Bleeding gum, cold, cough, dog bite and snake bite
4.	<i>Adhatodavasic</i> Nees.	Adathoda	Acanthaceae	Dicot	S	Wp	Asthma, sprains, cold, eczema and leucorrhoea
5.	<i>Aegle marmelos</i> (L.) Correa.	Vilvam	Rutaceae	Dicot	S	St, L & F	Wound healing, anti-oxidant, anti-diabetic
6.	<i>Aloe vera</i> (L.) Burm.f.	Sotrukatalai	Asphodelaceae	Monocot	H	M	Anti-Inflammatory, Anti-Aging, and antitumor
7.	<i>Andrographis paniculata</i> (Burm.f.) Nees.	Nilavembu	Acanthaceae	Dicot	H	Fl, L, R & La	Anti-cancer, anti-diabetic and anti-inflammatory
8.	<i>Annona squamosa</i> L.	Seethapalam	Annonaceae	Dicot	S	L, B, St, Se, Fr & G	Anti-dermatic, anti-pyorrhoeic and anti-scabic
9.	<i>Artabotrys hexapetalus</i> (L.f.) Bhandari.	Manoranjitham	Annonaceae	Dicot	S	L, B, St & Fl	Antipyretic, hepatoprotective and analgesic
10.	<i>Artocarpus heterophyllus</i> Lam.	Palamaram	Moraceae	Dicot	T	L, Fr & Se	Analgesic, anti-Pyretic and anti - diabetic
11.	<i>Azadirachta indica</i> A. Juss.	Veppamaram	Meliaceae	Dicot	T	Wp	Headache, diarrhea, cramps, dropsy and epilepsy
12.	<i>Borassus flabellifer</i> L.	Panaimaram	Arecaceae	Monocot	T	R, B, L	Analgesic, anti-microbial activity,





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						& La	purgative properties and procoagulant activity
13	<i>Calotropis gigantea</i> (L.) W. T. Aiton.	Erukku	Apocynaceae	Dicot	S	R, L & Se	Antiparasitic, antidiarrheal, anxiolytic & rubifacient
14	<i>Cardiospermum halicacabum</i> L.	Mudakaruttan	Sapindaceae	Dicot	H	L, Fr & Se	Anti-fertility, uterotonic, diuretic and hypolipidemic
15	<i>Carica papaya</i> L.	Pappali	Caricaceae	Dicot	H	R, L & F	Throat infections, chest complaints & asthma
16	<i>Cassia auriculata</i> L.	Avarampoo	Fabaceae	Dicot	S	S, L, Fl & Fr	Anti-bacterial, anti-diabetic, anti-diarrheal and anti-stress
17	<i>Cassia fistula</i> L.	Sarakondrai	Fabaceae	Dicot	T	R, L & Fr	Hypoglycaemic, antimalarial and anti-dyslipidaemia
18	<i>Catharanthus roseus</i> (L.) G. Don	Nithyakalyani	Apocynaceae	Dicot	S	S, L & Rh	Anti-ulcer, anti-cancer, promote fertility and hepatoprotective
19	<i>Clitoria ternatea</i> L.	Sangupoo	Fabaceae	Mono cot	H	L, R & Fl	Tuberculosis, bronchitis, rheumatic pain and swellings
20	<i>Coccinia indica</i> Wight & Arn.	Kovai	Cucurbitaceae	Dicot	H	Wp	Hemorrhoids, spleen enlargement and urinary tract infections
21	<i>Coleus amboinicus</i> Lour.	Karpuravalli	Lamiaceae	Dicot	H	Fr & Se	Bronchitis, cephalalgia and ophthalmopathy
22	<i>Cynodon dactylon</i> (L.) Pers.	Arugampul	Poaceae	Mono cot	H	L, B, Fr & Se	Bronchoconstriction activity, anti-diabetic, anti-fertility
23	<i>Cyperus rotundus</i> L.	Koraikizhangu	Cyperaceae	Mono cot	H	B, L & R	Antidiabetic, Antipyretic, anti-cancer and anti-allergic
24	<i>Datura metel</i> L.	Ummathai	Solanaceae	Dicot	S	R, L & Fl	Ocular infections, high blood pressure and kidney stone
25	<i>Eclipta alba</i> (L.) Hassk.	Vellaikarisalan ganni	Asteraceae	Dicot	H	L, B, R & Fl	Antioxidant, antimicrobial, anti-ulcer and anti-ulcer
26	<i>Erythrina variegata</i> L.	Kalyanamurugai	Fabaceae	Dicot	T	Wp	Rheumatism, anti-fungal and antineoplastic
27	<i>Ficus religiosa</i> L.	Arasamaram	Moraceae	Dicot	T	St, Fr & Se	Anti-hyperlipidemic, anti-inflammatory and cardioprotective
28	<i>Ficus benghalensis</i> L.	Aalamaram	Moraceae	Dicot	T	Wp	Headache, bronchitis, boils, ophthalmic,





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							syphilitic
29	<i>Heliotropium indicum</i> L.	Thelkodukki	Boraginaceae	Dicot	H	L, R & Fl	Antioxidant, antimicrobial and cytotoxic activity
30	<i>Hibiscus rosa-sinensis</i> L.	Semparuthi	Malvaceae	Dicot	S	L, St, B & Fl	Astringent, vermifuge, laxative and diuretic
31	<i>Jatropha curcas</i> L.	Kattamanakku	Euphorbiaceae	Dicot	T	L & R	Diabetes and cardiovascular diseases
32	<i>Lagenaria vulgaris</i> Ser.	Suraikai	Cucurbitaceae	Dicot	H	L, Fl, Fr & Se	Leprosy, dysentery, vaginal and uterine complaints
33	<i>Lawsonia inermis</i> L.	Maruthani	Lythraceae	Dicot	S	F & R	Respiration disorder, arthritis, gastric ulcer and heart diseases
34	<i>Leucas aspera</i> (Willd.) Link.	Thumbai	Lamiaceae	Dicot	H	L & Fr	Dysentery, vomiting, skin eruption and antiulcer activity
35	<i>Madhuca longifolia</i> (L.) J. F. Macbr.	Illupai	Sapotaceae	Dicot	T	Wp	Diabetes, hypertension, cancer, anti-ulcer and diarrhea
36	<i>Mangifera indica</i> L.	Mamaram	Anacardiaceae	Dicot	T	F, L, La & Fr	Antibacterial, anthelmintic, anti-inflammatory, hepatoprotective
37	<i>Manihot esculenta</i> Crantz.	Maravallikizhangu	Euphorbiaceae	Dicot	S	L, Fl, R & St	Analgesic, anticancer, antiasthmatic and antiemetic
38	<i>Manilkara zapota</i> (L.) P. Royen.	Sapota	Sapotaceae	Dicot	T	Wp	Astringent, stomachic, diuretic and wounds
39	<i>Mimosa pudica</i> L.	Thottasurungi	Fabaceae	Dicot	H	L	Bronchitis, epilepsy, vaginal discharge and vesicle calculi
40	<i>Morinda tinctoria</i> Roxb.	Nuna	Rubiaceae	Dicot	H	Wp	Anti-cancer, anti-diabetic, ulcer, leprosy and bronchitis
41	<i>Murraya koenigii</i> (L.) Spreng.	Karuveppilai	Rutaceae	Dicot	S	Wp	Gonorrhea, rheumatism, scabies, skin disease, diabetes, malaria and bleeding piles
42	<i>Musa paradisiaca</i> L.	Vazhai	Musaceae	Mono cot	H	L & Fr	Laxatives, anti-diabetic, anti-cancer, anti-diarrheal and anti-hypertensive





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43	<i>Nerium oleander</i> L.	Arali	Apocynaceae	Dicot	S	L, R & Se	Anticonceptive, antidiabetic and hepatoprotective
44	<i>Nyctanthes arbor-tristis</i> L.	Pavalamalli	Oleaceae	Dicot	S	Wp	Anti- proliferative, anti- inflammatory and anti-pyretic
45	<i>Ocimum basilicum</i> L.	Thiruneetrupac hillai	Lamiaceae	Dicot	H	L & R	Antimicrobial, anti-ulcerogenic, anti-platelet aggregation
46	<i>Ocimum sanctum</i> L.	Tulsi	Lamiaceae	Dicot	H	L, Fl, St & R	Tuberculosis, respiratory problem, anti- microbial and anti-inflammatory
47	<i>Paederia foetida</i> L.	Mudiyarkundal	Rubiaceae	Dicot	H	L, Se, fl, fr& R	Bronchial asthma, piles and dysuria, cytotoxic activities.
48	<i>Phyllanthusemblica</i> L.	Nelli	Phyllanthaceae	Dicot	T	St, Se, L & Fr	Anti- microbial, anti-inflammatory and anti-ulcerogenic
49	<i>Phyllanthus amarus</i> Schumacher. & Thonn.	Keezhanelli	Phyllanthaceae	Dicot	H	L, St, B & Fr	Syphilis, leprosy, gonorrhoea, antiparasitic and cure malaria
50	<i>Pongamia pinnata</i> (L.) Pierre	Punkaimaram	Fabaceae	Dicot	H	L, Se, B & Pu	Wound healing, snake bite, abdominal pain and fever
51	<i>Psidium guajava</i> L.	Guava	Myrtaceae	Dicot	T	Fr, L, R & Se	Anticancer, sedative, stomach ache, blood purifier and dyspepsia
52	<i>Punica granatum</i> L.	Mathulai	Lythraceae	Dicot	S	St, R & L	Anaemia, anorexia, diarrhoea, dysentery and dyspepsia
53	<i>Ricinus communis</i> L.	Amanakku	Euphorbiaceae	Dicot	S	L, R, B & Fr	Anti-diarrheal, anti-inflammatory, anti-spasmodic and anthelmintic
54	<i>Simarouba glauca</i> DC.	Paradise tree	Simaroubaceae	Dicot	T	Fr, La & B	Bladder stones, tooth cavities and inflammation
55	<i>Solanum nigrum</i> L.	Manathakkali	Solanaceae	Dicot	S	St, L & Fl	Gout, syphilis, piles, eye diseases and anti-



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							ulcer
56	<i>Solanum torvum</i> Sw.	Sundaikai	Solanaceae	Dicot	S	Fl& Fr	Urinary infections, digestive disorders and anti-diabetic
57	<i>Solanum trilobatum</i> L.	Thuthuvali	Solanaceae	Dicot	H	Se, L, Fl, B &Fr	Anti-helminthic, antipyretic and anti-inflammatory
58	<i>Solanum xanthocarpum</i> L.	Kadangkatarai	Solanaceae	Dicot	H	Se, L &Fr	Anticancer, anti-hypertensive, hepatoprotective
59	<i>Syzygium cumini</i> (L.) Skeels	Naval	Myrtaceae	Dicot	T	B, R, Fr& Se	Astringent, febrifuge, antibilious, antihelminthic and sedative
60	<i>Tabernaemontana divaricata</i> (L.) R.Br. ex Roem. &Schult.	Nandiavattai	Apocynaceae	Dicot	S	L, Se & R	Vaginal discharge, edema, helminthiasis and rheumatism
61	<i>Tamarindus indica</i> L.	Puliyamaram	Fabaceae	Dicot	T	L, Bu &Fr	Antimalarial, rheumatism, anti-ulcer, biliousness, constipation
62	<i>Vitex negundo</i> L.	Nochi	Lamiaceae	Dicot	T	F, St &Fr	Antioxidant, antimicrobial, anti-leishmanial and antifertility
63	<i>Ziziphus mauritiana</i> Lam.	Illanthai	Rhamnaceae	Dicot	S	L, Se & R	Headache, cough, diarrhea and constipation

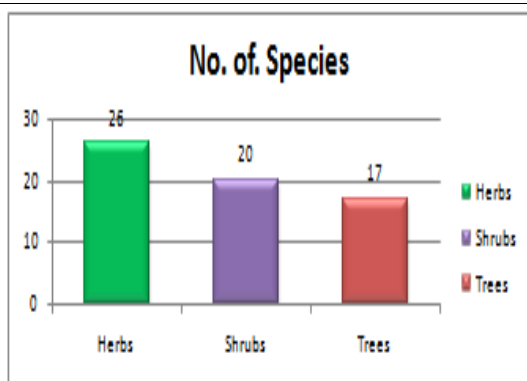


Figure -1 Different Habits of Marudhur Village, Karur

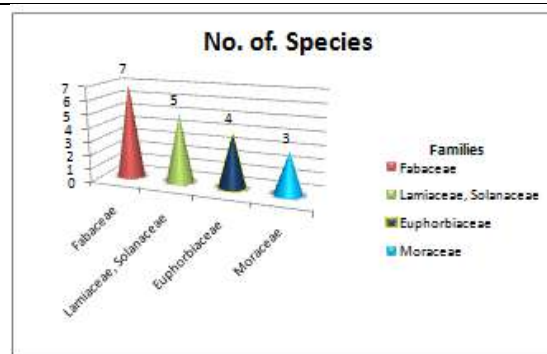


Figure -2 Familywise Distribution of dominant species of Marudhur Village, Karur





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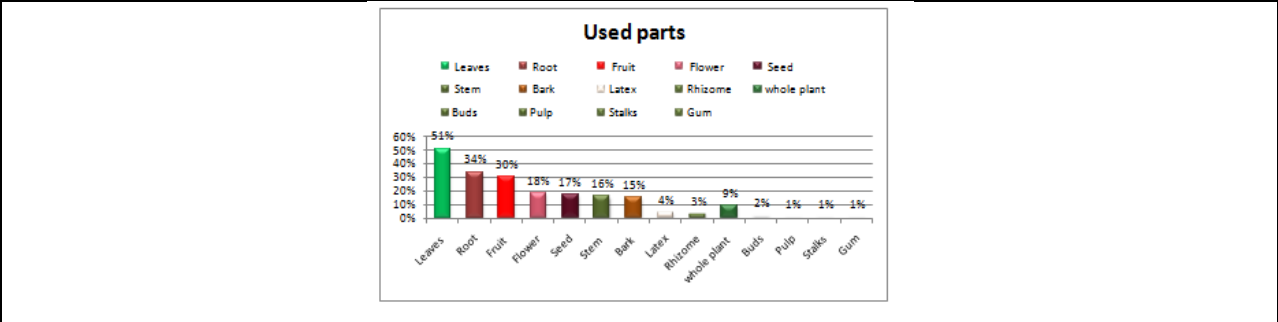


Figure - 3 :Medicinal plants parts wise usage of Mardhur Village, Karur

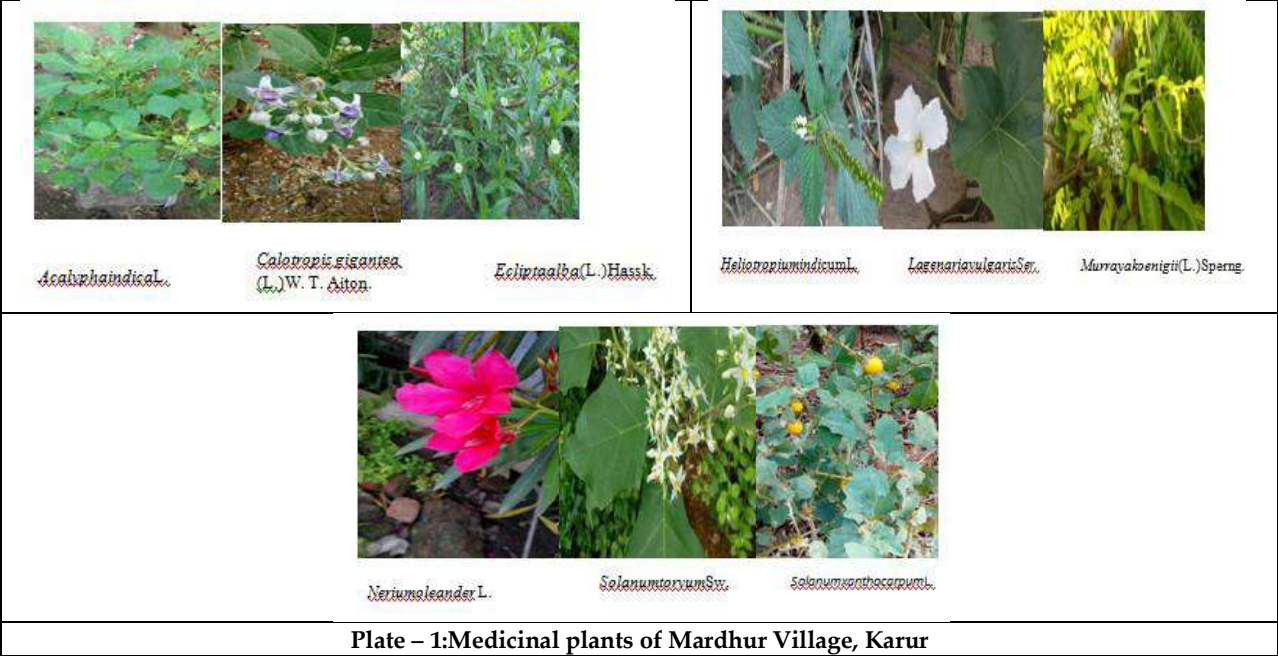


Plate – 1:Medicinal plants of Mardhur Village, Karur





Nutritional Interventions in Managing Behaviours of Children with Autism Spectrum Disorder- A Literature Review

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ABSTRACT

An increasing number of children are being diagnosed with autism spectrum disorder (ASD), a neuro developmental condition that impairs a child's ability to connect and communicate with others and their surroundings. Since there is no known cure for the condition, treatments often focus on speech and behavioral therapies to enhance the ASD-specific social, behavioral, and communication symptoms. Common comorbidities like digestive issues are regarded to not only be another sign of ASD but also to actively influence how the disorder manifests in social and behavioural symptoms. In order to treat gastrointestinal and behavioural problems, the majority of people with ASD adopt nutritional therapies, both with and without therapeutic supervision. This study aimed to investigate the behavioral problems seen in children with autism and discuss the potential nutritional interventions in reducing these problems. For pertinent studies, the databases Web of Science and PubMed were examined. The search was conducted using combinations of the terms "autism," "autistic," "nutritional intervention," and "behavior problem." Human studies examining the connection between nutritional intervention and behavioral issues in autism were included in the analysis. 27 studies were found in the initial search, 14 of which fully met the requirements for inclusion. By these investigations, we were able to ascertain the link between a child's diet and behavioural issues associated with autism and enhance their functionality. Published studies on the relationship of gastrointestinal and behavioural problems with gut microbiota in autism are very limited and contradictory. The fact that the results of the studies are not consistent with each other may be explained by the differences in the age of participants, geographical region, sample size.

Keywords: Nutrition, Intervention, Autism, behavioral problem



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INTRODUCTION

Autism is a neurobehavioral and cognitive condition that is characterized by repetitive behaviors, restricted imagination, impaired sociability, and communication. One of the most severe childhood diseases, autism affects almost one child in every 500. A spectrum of problematic behaviors are present in autism, which is a complex condition. Nevertheless, Desorgher et al. (2000) characterize autism as a neuro- gastro- immunological problem stemming from an immuno- genetic mistake during foetal development rather than a psychiatric condition. The most prevalent of these atypical behaviors include unusual eating patterns, irregular sleeping patterns, temper tantrums, and hostility towards oneself and others (Dominick et.al., 2007). Communication, social interaction, and behaviour are all impacted by the complex neurodevelopmental disease known as autism spectrum disorder (ASD). Although there is no known treatment for ASD, early intervention can help manage symptoms and enhance results. One sort of intervention that has been researched in the management of behaviours in children with ASD is nutritional intervention. We are aware that eating foods high in nutrients can help the body eliminate pollutants, build a strong immune system, control hunger, and avoid obesity. Eating disorders frequently have an impact on children with autism spectrum disorders (ASDs). Their propensity for nutrient-poor, high-energy foods can affect their metabolism, which can cause an accumulation of reactive radicals and a decline in both their mental and physical health. According to a recent report by the Indian Journal of Pediatrics published in 2021, the prevalence of autism spectrum disorder (ASD) in India is estimated to be around 1-2% among children aged 2-9 years. This suggests that there may be around 1.6 million children with ASD in India. This would make India the most populated nation in the world in terms of autistic patients, making recent advancements in autism research more pertinent to India. There are many different ways to treat autism, including medication, behaviour therapy, physical therapy, occupational therapy, and a number of complementary therapies. In many nations, particularly India, nutrition therapy for autistic children has not received the attention it deserves.

A series of metabolic and nutritional problems that autistic people experience have an impact on their health and behaviour. Williams et al. (2000) noted that children with autism usually experience substantial feeding challenges and have a very limited menu of food options. According to Lowe (2010), autistic children tend to decline more meals and limit their diets to fewer types of food than typical kids. All autistic children suffer from gastrointestinal issues, dietary intolerances, or nutritional deficits that are not properly treated. Many autistic children may also suffer from a subclinical nutritional insufficiency, which can lead to irritability, lack of focus, sadness, anxiety, disturbed sleep, or appetite loss (Strickland 2009). Those with autism spectrum disorders may have difficulty digesting casein, a protein found in milk and wheat, and gluten. Children with Autism Spectrum Disorder (ASD) have elevated amounts of certain peptides in their urine, which may indicate inadequate peptide breakdown. Peptides may disturb biochemical and neuroregulatory processes in the brain, disrupting brain functions, due to inadequate breakdown and excessive absorption. Some hypothesis that children with ASD have "leaky guts," or small holes in their intestinal tract, which may be caused by an overgrowth of yeast that produces toxic substances. Toxic metabolites from the gastro intestinal tract seep into the blood stream and contribute to behavioural and medical issues in people with autism, including confusion, hyperactivity, stomach issues, and fatigue. The basis of autism treatment is dietary intervention. The first step in enhancing the health and wellbeing of autistic children is to make thoughtful exclusions and additions to food choices. Some foods high in healing elements are advantageous when added to children's diets, while certain dietary substances are known to be hazardous and should be avoided (Matthews 2010). The aim of nutrition therapy for autism is to maximise the child's brain function so that the response to other treatments is improved and to support the child's body and brain structure to function at their best. In this review of the literature, we'll look at the research on nutritional therapies for children with ASD and how they affect behaviour.

1. Gluten-Free, Casein-Free (GFCF) Diet: Diet GFCF (Gluten-Free, Casein-Free) One of the nutritional therapies for ASD that has been most extensively researched is the GFCF diet. It entails removing from the child's diet everything containing casein, a protein included in dairy products, and gluten, a protein present in wheat,



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barley, and rye. Several studies have demonstrated that the GFCF diet can result in behavioural changes, such as decreased hyperactivity, increased concentration, and decreased irritability.

2. **Vitamin and Mineral supplementation:** Supplemental vitamin and mineral intake The impact of vitamin and mineral supplements on the behaviour of kids with ASD has also been studied. According to several studies, children with ASD are more likely to have nutritional deficiencies, and behaviour can be improved by taking vitamins and minerals supplements. In one study, for instance, it was discovered that children who received a multivitamin and mineral supplement exhibited improvements in communication and socialization skills.
3. **Omega-3 Fatty Acids:** Omega-3 fatty acids are necessary lipids that are extremely important for the growth and operation of the brain. According to several research, giving children with ASD omega-3 supplements may help them behave better. One study, for instance, discovered that youngsters who took omega-3 supplements had improvements in hyperactivity, stereotypy, and communication.
4. **Probiotics:** Live bacteria and yeasts known as probiotics are good to human health. The gut-brain axis, or connection between the gut and the brain, is thought to include them. Probiotics have been studied as a possible dietary intervention for kids with ASD. According to one study, kids who took a probiotic supplement displayed improved behaviour, including less irritation and hyperactivity.

RATIONALE

A developmental disorder known as autism spectrum disorder (ASD) is marked by deficiencies in social communication, impaired social engagement, and repetitive and stereotyped activities. In addition to behavioural problems, children with ASD are more likely to experience gastrointestinal difficulties, food preferences, and nutritional deficits. The rationale for nutritional interventions in managing behaviors of children with ASD is based on the following:

1. **Nutritional deficits:** Due to their restricted diets and picky eating habits, children with ASD are more prone to suffer nutritional deficiencies. These inadequacies may exacerbate their behavioural issues, further isolating them from society and lowering their quality of life. Dietary supplements and other nutritional interventions can assist to address these deficiencies and enhance general health.
2. **Food sensitivity:** ASD children may have food sensitivities, which can lead to behavioural problems. Their behavioural problems can be improved by identifying and removing certain trigger foods from their diet.
3. **Digestive problems:** Children with ASD are more prone to have digestive problems include constipation, diarrhoea, and pain in the abdomen. An increase in irritation and behavioural issues can result from these symptoms. Interventions in nutrition can help reduce these symptoms and enhance general health.
4. **Imbalances in neurotransmitters:** According to research, children with ASD may experience unbalances in dopamine and serotonin, which may be a factor in their behavioural symptoms. Specialized diets and nutritional supplements can help balance these neurotransmitters and reduce behavioural problems.
5. **The gut-brain axis:** There is mounting proof that the gut microbiota affects how the brain and behaviour are developed and regulated. The gut health of children with ASD can be improved by nutritional therapies, such as probiotics and prebiotics, which may also help with behavioural symptoms. Overall, addressing nutritional deficiencies, removing trigger foods, relieving gastrointestinal symptoms, balancing neurotransmitters, and improving gut health are the justifications for nutritional interventions in regulating behaviours in children with ASD. There is evidence that suggests nutritional therapies may be a helpful complement to behavioural and pharmaceutical interventions in controlling the symptoms of ASD, though the study is still in its early stages.

INTERNATIONAL STATUS

A topic of attention around the world is the use of nutritional therapies in controlling the behavior of kids with autism spectrum disorder (ASD). Guidelines for their use have been released by a number of international organisations that have acknowledged the potential advantages of dietary therapies in treating ASD symptoms.



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The American Academy of Pediatrics (AAP) advises that gastrointestinal symptoms and nutritional inadequacies in children with ASD be assessed, and that suitable therapies be used to address these problems. The AAP also acknowledges the potential advantages of specific dietary therapies, including omega-3 fatty acid supplementation, in enhancing behaviour and cognitive function in kids with ASD. Guidelines for the identification and treatment of gastrointestinal issues in children with ASD have been released by the European Society for Paediatric Gastroenterology Hepatology and Nutrition (ESPGHAN). In order to treat gastrointestinal issues in kids with ASD, the recommendations suggest using a gluten- and casein-free diet. The World Health Organization (WHO) understands how critical it is to meet the nutritional requirements of kids with developmental disorders, including ASD. The WHO advises providing children with ASD with a nutritious diet that is both balanced and varied.

Children with ASD in Australia can get support for nutrition-related interventions, such as nutritional assessments and supplements, under the National Disability Insurance System (NDIS). In conclusion, the potential advantages of dietary therapies in controlling the behaviors of children with ASD are acknowledged on a global scale. Many organizations have released guidelines and recommendations in favour of the use of these therapies in the treatment of ASD symptoms. To completely comprehend the usefulness of nutritional therapies in treating ASD symptoms and to create evidence-based recommendations for their application, more study is necessary.

NATIONAL

In India, there is a growing area of research on nutritional therapies for treating ASD-related disorders in kids (ASD). Other pertinent studies include:

1. Srinivasan et al. (2018) did a study to look at how a gluten-free and casein-free diet affected the behavior and cognitive function of Indian children with ASD. According to the study, the children's behavior, attention, and communication all improved after they changed their diet.
2. In a second study, Tandel et al. (2019) examined the impact of an omega-3 fatty acid, vitamin, and mineral supplement on the behavior of ASD-afflicted children in India. According to the study, children's behavior and social skills significantly improved as a result of taking the supplement.
3. An investigation of the incidence of nutritional deficits in Indian children with ASD was conducted by Krishnaswamy et al. (2018). According to the study, vitamin D, vitamin B12, and iron deficits were common among children in India with ASD.
4. Children with ASD exhibited different levels of gut bacteria than children who were typically developing, which may explain their gastrointestinal symptoms and behavioural issues, according to a 2018 Indian study by Marwaha et al. According to the study, probiotic therapies may be helpful in treating these symptoms. According to these studies, specific diets and nutritional supplements may be useful in regulating the behaviors of Indian children with ASD. To completely comprehend the efficacy and safety of these therapies, as well as to create evidence-based recommendations for their application in the Indian setting, more research is nonetheless required.

METHODS

We originally searched PubMed and Web of Science for papers between the years 2000 and 2020 using the medical subject heading (MeSH) phrases terms "autism," "autistic," "nutritional intervention," and "behaviour problem". As there wasn't enough information, we added another 20 years to the total, bringing it up to 1980. This search turned up 69 papers, all of which were in English. We used the population's inclusion criteria, which included being under 18, all human research, and having free full-text papers available. It produced 30 papers, including surveys, case-control studies, literature reviews, and meta-analyses. With the identical search terms on Google Scholar, we received 200 results; but, after applying all the inclusion criteria outlined above, we only received 11 items that were significant to us. 27 studies were found in the initial search, 14 of which fully met the requirements for inclusion. By these investigations, we were able to ascertain the link between a child's diet and behavioural issues associated with autism and enhance their functionality.



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REVIEW OF LITERATURE

Gluten-Free, Casein-Free (GFCF) Diet

An increasing number of studies is looking into how well a gluten-free, casein-free (GFCF) diet controls behavior in kids with autism spectrum disorder (ASD). These are some important conclusions from recent research:

1. The GFCF diet may be helpful in lowering ASD-related symptoms, particularly in the areas of communication, socializing, and repetitive behaviors, according to a systematic review and meta-analysis of 27 research (Mazzone et al., 2018).
2. In a randomized controlled experiment with 72 ASD children, those who adhered to the GFCF diet for six months had significant behavioural and physiological benefits when compared to those who followed a conventional diet (Elder et al., 2006).
3. A comprehensive analysis of 15 research on the application of dietary treatments, such as the GFCF diet, in children with ASD was carried out in one article that was published in 2015 in the Journal of Autism and Developmental Disorders. The GFCF diet is one of the most popular dietary therapies for ASD, but the study revealed that there is little evidence to support its use in controlling ASD-related behaviors.
4. A GFCF diet was linked to enhancements in socializing, cognitive function, and behavior in certain kids with ASD, according to a 2013 study that appeared in the Journal of Child Neurology. 30% of the 387 ASD participants in the research followed a GFCF diet. In comparison to individuals who did not follow the regimen, the researchers discovered that those who did so significantly improved their conduct, socializing, and cognitive function. The fact that the study was not a randomized controlled trial and depended on parental reports of dietary consumption and behavioral changes, however, placed limitations on it.
5. 98 children with ASD, a more recent randomized controlled experiment compared the GFCF diet to a control diet. The results were published in 2019 in the Journal of Autism and Developmental Disorders. Between the two groups, there were no discernible differences in behaviour, cognition, or socialization, according to the study. The study was, however, constrained by its small sample size and brief intervention period. In the past 20 years, there has been a marked increase in research on diet and nutrition in autistic and ASD children, with a focus on studies of hyperactivity and attention. In 2016 and 2013, respectively, Catassi et al. and Cruchet et al. conducted two separate investigations on nonceliac gluten sensitivity-based, gluten-free diet trials on autistic and ASD children. The gluten-free diet kind of test, which was initially carried out in the 1980s and lately rediscovered, theorized a possible increase in peptide creation due to inadequate and inappropriate digestion of meals containing gluten and casein. These peptides may pass the blood-brain barrier due to the "leaky gut" characteristic prevalent in autism and ASD, altering the endogenous opiate neurotransmission systems. By getting rid of these 'toxins,' the kids are better able to control their behaviour and emotions. When Robertson et al. compared the original research on intestinal permeation conducted by Lau et al., they did not discover any alterations in intestinal permeability as claimed by the later. There is still more evidence to support these impacts, despite the prevalence of testing various food regimens on young children and all this research. Overall, there is conflicting and inconclusive information supporting the GFCF diet's ability to control the behaviors of children with ASD. While some research has indicated that the GFCF diet might help certain kids with ASD, other research has revealed no appreciable effects. To fully comprehend the possible advantages and restrictions of the GFCF diet in the control of ASD-related behaviors, more study is required.

Vitamin and Mineral supplementation

Although vitamins and dietary supplements have been proposed as potential treatments for autism spectrum disorder (ASD) symptoms, there is scant scientific support for their efficacy. Below is a quick summary of several recent studies that are pertinent to this subject. 18 randomised controlled studies exploring the use of different vitamins and supplements in kids with ASD were examined in a 2019 systematic review article published in the Journal of Autism and Developmental Disorders. While some supplements, such omega-3 fatty acids, showed promise in alleviating some ASD symptoms, the study found that there was inadequate data to recommend the use of the majority of other supplements. Vitamin D is one dietary supplement that has undergone substantial research. A systematic analysis from 2020 indicated that children with ASD frequently have low levels of vitamin D, and that



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vitamin D treatment might help with ASD symptoms, particularly social communication. The analysis found that additional studies are necessary to fully comprehend the possible advantages and recommended vitamin D dosage for kids with ASD. Melatonin, a hormone that controls sleep-wake cycles, is another supplement that has been researched. A 2017 meta-analysis indicated that melatonin supplementation may enhance sleep quality and lessen insomnia in kids with ASD. This finding was published in the Journal of Clinical Medicine. The study did point out that further investigation is required to establish the ideal dosage and long-term security of melatonin use in this population. Probiotics, vitamin B6, and folic acid are some other dietary supplements that have been researched in relation to ASD. To ascertain their possible advantages and dangers, additional research is required because there is little proof on their efficacy. Children with autism and ASD require vitamin and mineral supplements since they are thought to be very beneficial. For countless biochemical enzymatic reactions in our bodies, several of these vitamins and minerals function as co-enzymes and neurotransmitters. In a three-month, randomised control trial, Adams et al. discovered that deficiencies in vitamins and minerals can affect metabolic function. In addition to improving biotin, oxidative stress, glutathione, methylation, adenosine triphosphate (ATP), the reduced form of nicotinamide adenine dinucleotide phosphate (NADPH), and sulphate, the study found that the supplements also reduced hyperactivity, tantrums, and general language reception with fewer side effects. Studies by Buie et al., Horvath et al., and Ashwood et al. demonstrated that a ParentScore on the Parent Global Impression-Revised (PGI-R) significantly increased. A child's PGI-R score, which takes into account many variables including pain and hunger that can be evaluated, is a sign of psychosocial impairment in children with special needs. It assesses the efficacy of all therapies provided to autistic children and has good sensitivity, specificity, consistency, reliability, and validity. These studies' shortcomings included their limited sample size and need for in-depth investigation. Overall, there is little and conflicting data supporting the use of vitamins and nutritional supplements to treat ASD symptoms. While some dietary supplements might be able to improve some elements of ASD, additional research is required to fully appreciate their potential advantages and disadvantages. Before beginning any supplement regimen for a child with ASD, it is crucial to speak with a healthcare practitioner as with any other treatment strategy.

Omega-3 Fatty Acids

Due to their involvement in brain development and function, omega-3 fatty acids have been investigated as a potential treatment for autism spectrum disorder (ASD). Below is a quick summary of several recent studies that are pertinent to this subject. The use of omega-3 fatty acid supplements in kids with ASD was the subject of 12 randomised controlled trials, which were examined in a 2019 systematic review and meta-analysis published in the journal Molecular Autism. According to the study, giving children with ASD omega-3 fatty acid supplements was linked to a considerable improvement in their communication, stereotypy, and hyperactivity. The study did point out that further investigation is required to establish the ideal omega-3 fatty acid supplementation regimen, duration, and timing for this population. Another 2014 study that appeared in the Journal of Child Neurology looked at how omega-3 fatty acid supplementation affected the behaviour and cognitive of kids with ASD. 57 children with ASD were enrolled in the trial, and 31 of them received omega-3 fatty acid supplements while the remaining 26 received a placebo. In comparison to individuals who received a placebo, the study discovered that those who received omega-3 fatty acid supplements significantly improved their social interaction and hyperactivity. In a 2017 randomised controlled experiment, the benefits of omega-3 fatty acid supplementation on parent-reported problem behaviours in kids with ASD were investigated. The results were published in the Journal of Child Psychology and Psychiatry. 57 children with ASD were enrolled in the trial, and 29 of them received omega-3 fatty acid supplements while the other 28 received a placebo. In comparison to individuals who received the placebo, the study discovered that those who received the omega-3 fatty acid supplements significantly reduced their levels of hyperactivity, irritability, and stereotypy. Overall, the data point to omega-3 fatty acid supplementation as a potentially effective therapy strategy for addressing several ASD-related symptoms, including hyperactivity, stereotypy, and communication. The ideal supplementation dosage and duration as well as the long-term efficacy and safety of this method, however, still require further study. It's crucial to speak with a medical practitioner before beginning an omega-3 fatty acid supplementation programme for a child with ASD, as it is with any therapeutic strategy.



**Umera Begam and Sasikala Hephzibah****Probiotics**

Based on their ability to affect the gut-brain axis and the microbiome, probiotics—live bacteria thought to have health benefits—have been investigated as a potential treatment for autism spectrum disorder (ASD). Below is a quick summary of several recent studies that are pertinent to this subject. A 2017 comprehensive review and meta-analysis of 10 randomized controlled trials looking into the use of probiotics in children with ASD was published in the journal *Frontiers in Psychiatry*. According to the study, probiotic supplementation was linked to appreciable gains in social interaction and conduct in kids with ASD. The study did point out that more investigation is required to establish the best probiotic strains, doses, and administration times for this population. Another 2016 study that appeared in the *Journal of Clinical Psychopharmacology* looked at how *Bifidobacterium longum*, a particular probiotic strain, affected the behaviour and cognitive of young ASD patients. 44 children with ASD participated in the trial, and 22 of them received *B. longum* while the other 22 received a placebo. In comparison to those who received the placebo, individuals who received *B. longum* shown appreciable gains in social conduct and communication, according to the study. In a 2019 randomized controlled trial, the benefits of a probiotic and prebiotic combo supplement on behavior and gastrointestinal symptoms in kids with ASD were investigated. The results were published in the journal *Nutrients*. 75 kids with ASD were enrolled in the trial, and 38 of them received the supplement while the other 37 received a placebo. Comparing those who received the supplement to those who received a placebo, the study indicated that those receiving the supplement significantly improved their social interaction and gastrointestinal problems. Overall, the data points to probiotic supplementation as a potential therapy strategy for controlling various ASD-related symptoms, particularly social behaviour and communication. The best strains, doses, and length of supplementation, as well as the long-term efficacy and safety of this strategy, still require further study. Before beginning probiotic supplementation for a child with ASD, it is crucial to speak with a healthcare practitioner as with any other therapy strategy.

DISCUSSION

As a potential treatment for controlling the behaviours of autistic children, nutritional intervention is receiving more and more attention. A growing amount of research has recently examined the connection between diet and behaviour in autistic kids. This review tries to compile the body of knowledge on dietary management of autistic children's behaviour. According to a number of studies, kids with autism may require special dietary needs, such as those related to vitamin, mineral, and other nutrient shortages. For instance, research by Adams et al. (2011) indicated that children with autism had lower levels of calcium, selenium, and the vitamins C, D, and E than children who were typically developing. Deficits like these could be a factor in issues with aggression, hyperactivity, and self-harming behaviour. Studies have looked into the use of dietary supplements, such as probiotics and omega-3 fatty acids, as a nutritional intervention for controlling behaviour in autistic kids. According to a review by Mazahery et al. (2019), omega-3 fatty acid supplementation may help children with autism who exhibit hyperactivity and inattention. To find the ideal amount and duration of omega-3 supplementation, more research is required because the evidence is not consistent across different trials. Probiotics, live bacteria that have been shown to have health advantages when taken, have also been investigated as a potential treatment for autism-related behavioural issues in young children. In children with autism, probiotic supplementation improved gastrointestinal symptoms and decreased irritability, according to a randomized controlled experiment by Pärtty et al. (2015). The usefulness of probiotics for controlling behaviours in this population, however, requires further study. Dietary therapies, such as the gluten-free, casein-free (GFCF) diet, have also been researched as prospective interventions for controlling behaviours in autistic kids in addition to supplements. Casein, a protein included in milk and dairy products, and gluten, a protein present in wheat, barley, and rye, are both prohibited on the GFCF diet. According to some research, the GFCF diet may help children with autism who exhibit traits including irritability, hyperactivity, and social withdrawal. To establish the efficacy and safety of this dietary intervention, more study is required because the evidence is not consistent across all studies. Overall, the body of research points to dietary intervention as a potentially effective strategy for controlling behaviours in autistic kids. However, further investigation is required to establish the best dietary and



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nutritional supplement interventions, dosages, and durations, as well as the possible dangers and advantages of such interventions.

CONCLUSION

The research on nutritional treatments for behaviour management in kids with autism spectrum disorder (ASD) indicates that dietary treatments and supplements may be effective. According to a number of studies, children with ASD may have particular nutritional requirements and deficits that might lead to behavioural issues. While there is some evidence that supplements like probiotics and omega-3 fatty acids may benefit specific behaviours, further research is required to establish the ideal supplement dosages and duration. Also investigated as a potential therapeutic, the gluten-free, casein-free (GFCF) diet has shown promise in improving several behaviors in ASD youngsters. To ascertain its efficacy and safety, more research is required because the evidence is not uniform across various investigations. Overall, future research into nutritional therapies for controlling behaviors in children with ASD is promising. Therefore, it is crucial to move slowly and carefully with the advantages and disadvantages of any dietary intervention. To better understand the underlying mechanisms by which dietary interventions may affect behaviour in kids with ASD and to determine the most efficient and secure approaches to enhance their health and wellbeing, more research is required.

FURTHER RESOURCES

Nutritional Neuroscience published an article by Laura Gómez-Gómez et al. titled "Nutritional status and gastrointestinal symptoms in children with autism spectrum disorder" (2020). In this study, gastrointestinal symptoms and nutritional status in kids with ASD are compared. Journal of Autism and Developmental Disorders published "A comprehensive assessment of the effectiveness of dietary therapies for children with autism spectrum disorders" by Joanne Lau et al (2018). The effectiveness of dietary therapies for kids with ASD, such as a gluten-free, casein-free diet and omega-3 fatty acid supplementation, is reviewed in this article. Sabina Ramirez-Salazar et al., "Effectiveness of Nutritional Treatments on Language Development in Children with Autism Spectrum Disorder: A Comprehensive Study," in *Nutrients* (2021). The impact of nutritional therapies for language development in kids with ASD is examined in this study. Margaret L. Bauman and Katherine L. Kemp published "The use of dietary treatments in the treatment of autism spectrum disorders: a comprehensive review" in the *Journal of Autism and Developmental Disorders* (2012). The summary of dietary therapy for ASD in this article covers both their potential advantages and drawbacks. Stephen Genuis and Isaac J. R. Wantuck's "Nutritional therapies for autism spectrum disorder" is published in *Nutrition in Clinical Practice* (2016). This article summarizes the research supporting nutritional therapy for ASD and explores the prospects and difficulties of putting such interventions into practice. These resources might offer further details and viewpoints on the application of nutritional therapies for controlling behaviour in ASD kids.

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Impact of Wildlife Trafficking and Poaching on Tiger (*Panthera tigris*) Population in India: A Comprehensive Review

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ABSTRACT

The purpose of this study is to review the impact of Wildlife trafficking and poaching on tiger population in India. a comprehensive review has been conducted here to know illegal trafficking and poaching of tiger scenario in India. This review has revealed that widespread poaching and trafficking threaten tiger population of India. as the demands for different body parts of Tiger is increasing across different nations, the rate of illegal tiger trafficking or poaching is also increased in this country. Despite conservation efforts, illegal activities persist. Effective legislation, community engagement, and economic development are essential. Collaborative data sharing can identify high-risk areas, enabling targeted interventions to protect tigers from imminent threats.

Keywords: Wildlife traffic, Tiger poaching, Tiger conservation, Wildlife protection, Tiger Population

INTRODUCTION

“Poaching” and “illegal wildlife trafficking” are significant dangers to biodiversity, particularly when it comes to endangered species. Tigers are known as iconic creatures, and this species’ body parts are highly valued in both



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domestic and foreign criminal markets. Despite having several rules and strict enforcement, trafficking or poaching is at its highest in India, which is the largest tiger conservation unit in the world[1]. Habitat loss has become one of the biggest threats to the survival of wild tigers in India. According to a recent report, India ranked at the 4th position for wildlife crime across the world. It is now known that an even greater threat is being posed by the trade of tiger bones that are intended for use in Oriental medicine outside of India[2]. Manufacturers of traditional medicines from the Far East are now focussing on India for their supply of tiger bones after destroying their own sources. However, since India is home to the world's biggest population of wild tigers, illegal tiger poaching and trafficking pose serious dangers to biodiversity. Because of the strong demand for tiger body parts in both domestic and foreign markets, poaching rates have increased despite strict regulations and conservation efforts. Tigers are the main target of this illicit traffic, which is worth between \$19 and \$26 billion a year, because their bones, skins, and other body parts are used in luxury products and traditional medicine[3]. Additionally, the issue is made worse by habitat loss, which makes conservation efforts more difficult. The severity of this problem is highlighted by the startling fact that wildlife crime in India ranks fourth globally. By taking all these aspects into consideration, this current review has focused on the impact of Wildlife trafficking and poaching on tiger population in India.

Tiger conservation in India

India has the world's largest tiger conservation unit, yet despite the country's tough rules and enforcement, poaching is at an all-time high. The goal of India's tiger conservation is to preserve the biggest number of wild tigers in the world, which are a representation of the country's abundant biodiversity. In 1973, the Indian government started Project Tiger, a historic program that created protected areas and attempted to stop habitat degradation and poaching[4]. According to the most recent census, the number of tigers has expanded dramatically as a result of this effort, from about 1,800 in the early 1970s to over 2,900 by 2018[5]. However, "the Sundarbans National Park (SNP)" is the largest "tiger reserve", "national park", and "bio-sphere reserve" in west Bengal, India[6]. However, with its forthcoming functions, the Sundarbans Tiger Reserve has encountered a variety of situations. The clash between humans and tigers has been an issue, according to the roving tigers. It has been estimated that hundreds of native people have been mercilessly murdered by Sundarbans tigers over the previous forty years[7]. Tigers in the Sundarbans region hunt people. It has not yet been determined how many tigers are present on the reserve using a sophisticated method. The state equal direction-finding panel, led by the chief minister, and the reserve, in particular the Tiger Conservation Foundation, have been expected to include the tiger preservation strategy as constituents. Despite these advancements, problems still exist. Three major risks still exist, including illegal wildlife trafficking, habitat fragmentation, and human-animal conflict. Although protected sites like Jim Corbett, Ranthambore, and the Sundarbans are important habitats, surrounding communities and development activities frequently put strain on them.

Purpose of wildlife trafficking

Wildlife trafficking refers to the unlawful possession, transportation, taking, or trading of animals or their derivatives in violation of national, international, and regional laws[8]. In addition to violating animal rights, wildlife trafficking is a growing global issue that poses a harm to the environment, society, and economy. It has a negative impact on people's well-being and supports an illicit economy. Based on the previous relevant cases and literature, it has been noted that there are many purposes for wildlife trafficking and poaching across the world. For instance, it has been noted that Wildlife products are frequently valued as luxury goods in many nations. For example, it is seen as a prestige symbol to possess jewellery, carvings, or artwork made from rhino horn or ivory[9]. Some wildlife items are used for bribes (in other criminal organisations) or gift-giving in addition to their personal value. Wildlife that has been trafficked, usually birds and reptiles, are also frequently used in the exotic pet trade. In this context, some specific animal parts such as tiger bones or teeth, pangolin scales and rhino horns are used in different traditional medicine making. According to a report by the World Health Organisation (WHO), 88% of member states recognise the practice of traditional medicine[10]. Traditional medicine is a more important healthcare resource in China, India, and a number of African nations. In 2020, it was predicted that traditional medicine in China was worth over \$40 billion USD[11]. Unfortunately, overharvesting and poaching are causing populations of several animal products used in traditional medicine to decline below sustainable levels. Moreover, hunting or poaching wild animals for



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food has also been a necessary and common practice for thousands of years[12]. Therefore, reviewing the relevant literature, it has become clear that there are a range of reasons behind the illegal hunting, trafficking or poaching of different wildlife animals. In this context, as per recent reports and research, every part of a tiger's body has a market value[13]. Their bones are utilised in traditional medicines and also these parts are boiled down in terms of making tiger bone glue, or steeped in wine. On the other hand, their skins are also used for clothing or rugs. Furthermore, their teeth and claws are used to make amulets and trinkets; their meat is eaten and even their whiskers are highly valued in black markets.

Poaching and trafficking threats to Tiger in India

The illegal trafficking of endangered species or wildlife animals' commercially valuable body parts has a sophisticated global network. In nations with abundant biodiversity, such as India, such practices are extremely concerning since they undermine conservation efforts¹. According to current reports, the population size of wild tigers has decreased worldwide by half in the past 20 years¹⁴. They are excessive susceptible to poaching because of the rise in demand for body parts; because of this reason, between 2000 and 2018, different law enforcement organisations confiscated 2,359 tiger parts worldwide[1]. Most of the bones, flesh, and other components are generally found in the northern and eastern states that border each other. In this context, the intensity of seizures has been found to be very high in the states of Tamil Nadu, Karnataka, Assam and Maharashtra[15]. Four trade routes, including the Nepal-Bhutan border, the Assam border, the Mumbai port and the Brahmaputra, have been highlighted for the export of the seized parts of Tiger across India. However, this is in line with India's five tiger protection blocks, and the Western Ghats region has a high seizure rate, which has not yet been identified. On the contrary, another literature has argued that the Indo-Chinese border is the main illegal trade route for tiger body parts is across[16]. India has the most tiger seizures globally and is a major tiger habitat[17]. The extensive employment of contemporary firearms in the late 1800s marked the beginning of the Indian tigers' predicament. Even with stringent laws such as the Wildlife Protection Act 1972 and its 2006 tiger amendment, poaching still happens in India. During 1994 and 2003, it was reported by "the Environmental Investigation Agency (EIA)" that more than 684 cases of tiger poaching and seizure occurred in India.

Apart from that, India lost almost 1,110 tigers between 1994 and 2016¹. Another report has also indicated that around 369 tiger seizures took place in India between 2000 and 2018, which is more than any other tiger range country[18]. On the other hand, a recent study has shown that between January 2000 and June 2022, more than 2,205 poaching instances occurred in 50 nations and territories worldwide, resulting in the confiscation of 3,377 tigers. In the past 22 years, 893 (26% of all tigers) have been seized in India, which has the most seizure incidents (759; 34% of all tigers)[19]. These reports indicate that there has been a significant growth in Wildlife trafficking over recent years. However, it has been noted that Tribes have a great deal of experience in handling and moving animals, and many of their hamlets are located inside reservations. Another study has indicted that in India, during the COVID-19 lockdowns, tiger poaching reached a height of 151%[20]. Studies examining the effects of tiger poaching on the ecosystem and the individuals involved have not been conducted. Poachers use this since it can be difficult to police tough laws in a scheduled tribal hamlet. The extent of tiger poaching and the beginnings of trade channels are not well understood in the Indian context. The India-China-Nepal trafficking route and the severity of seizures in states bordering China and Nepal are the main topics of the majority of the literature on tiger trading and poaching[1]. Additionally, they predict a commerce route with China as the main customer that passes through Ladakh, Tibet, Laos, and Bhutan. Studies mostly concentrated on identifying and enhancing tiger habitats and populations, with little attention paid to domestic demand or the origin of the trade route. However, a recent study has indicated that there is a greater demand for skin, claws, bones, and teeth, with local markets favouring the teeth and nails of tigers. Previous studies have indicated that the skin, fat, claws, teeth, meat, genitals, and even bones of Tiger are poached for the purpose of traditional medicines[21]. In addition to that, other body parts, such as whiskers, eyeballs, and tails, are also used in making different types of medicine. In this context, China has been found as the main consumer of such tiger trafficking activities in India as there are high.



**Kaji Mainuddin et al.,****Impact of Wildlife trafficking and poaching on tiger population in India**

Tiger populations in India have been severely harmed by wildlife trafficking and poaching, which poses a serious threat to their survival. India has the highest tiger population in the world, but illegal hunting brought on by the market for luxury products and traditional medicine is making matters worse. Tigers are at the heart of India's wildlife crime epidemic, which is estimated to be worth between \$19 and \$26 billion a year[22]. On the other hand, "Panna Tiger Reserve", in Central India lost all its tigers in 2009 due to huge rage of wildlife trafficking or poaching practices. This loss of entire populations in reserves like Panna, where all tigers were exterminated by 2009, is an example of how poaching has caused sharp drops in tiger populations. Over 2,300 tiger parts were confiscated by law enforcement worldwide between 2000 and 2018, underscoring the scope of the trafficking network[23]. The problem is made worse by habitat loss brought on by agriculture and urbanization, which increases tigers' susceptibility to poaching. The tiger population in India, which is home to the greatest number of wild tigers worldwide, is severely impacted by wildlife trafficking and poaching. Despite strict regulations and conservation efforts like Project Tiger, the illicit trade remains a serious concern because of the demand for tiger body parts in luxury goods and traditional medicine. According to studies, poaching rates have dramatically increased, particularly during the COVID-19 outbreak[24]. The issue is made more difficult by habitat loss, as growing human activity encroaches on tiger habitats, increasing conflict between humans and wildlife. Over the course of the last century, India's tiger population is thought to have declined substantially, with illegal poaching playing a major role. The general trend is still alarming, even though certain areas, like the Sundarbans, are showing signs of recovery.

Enforcement measures are complicated by the intricacy of trafficking networks, which frequently operate internationally[25]. The survival of tigers in India is still uncertain unless swift and concerted action is taken, combining habitat preservation, community involvement, and legal measures. Resolving these problems is essential for preserving biodiversity and ecological balance in the area as well as for the survival of this iconic species. However, Royal Bengal Tiger is one of the identify and significant marks of India but this species is at high threat to habitat loss. For instance, a recent news report has indicated that the combined threats of poaching, trafficking, habitat loss, global warming and urbanization has caused India to lose 97% of its Bengal Tiger population in the last century[26]. On the contrary, another report argues that the number of tigers in the Sundarbans shows a rise in the next census as there is no significant threat of saturation. Apart from that, there is also no threat to sufficient prey base in the 4,200 sq km area around the mangrove forest[27]. According to this report, the number of tigers was 88 in 2018 in Sundarbans which went up to 101 in 2022[27]. However, as poachers frequently take advantage of enforcement weaknesses, the rise of organised crime in wildlife trafficking makes conservation efforts more difficult. Poaching rates increased despite tougher regulations and government programs like Project Tiger, particularly during the COVID-19 pandemic[28]. The stability of India's tiger populations is in jeopardy due to the combination of these causes, which makes immediate and concerted conservation measures necessary to successfully battle poaching and trafficking.

Legal Initiatives to minimizing Tiger Poaching or trafficking occurrences in India

Under "the Wildlife (Protection) Act of 1972", it is illegal to trade in more than 1800 species of wild animals, plants, and their derivatives[29]. This law aims to prohibits the illegal capturing, killing, buying and selling of animals across the country. After the "Wildlife Protection Act" was put into effect in 1972 and cases were documented in the 1980s, the handling and trafficking of tiger parts was outlawed in India. Due to their healthy tiger populations, southern Indian states have the highest number of tiger smuggling instances. The network of illegal trafficking expanded to cover Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, Bihar, Maharashtra, Karnataka, and Bengal. For example, according to a recent report, two poachers were arrested by the wildlife wing of the forest department" as they were wanted to hunt a Royal Bengal Tiger in "Similipal Tiger Reserve" in 2021[30]. As per the Indian law, this case was non-bailable and due to this reason, they are still in the judicial custody. Apart from that the Project Tiger government program that focusses on habitat preservation and anti-poaching tactics. Numerous tiger reserves have been established as a result, and patrolling efforts have risen. In order to dismantle transnational trafficking networks, the government works with non-governmental organisations (NGOs) and foreign agencies like the Environmental Investigation Agency (EIA)[31]. Moreover, specialised anti-poaching units, awareness campaigns,



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and community engagement initiatives that motivate locals to take part in conservation initiatives are examples of state-specific strategies. Successful arrests in recent years demonstrate the value of community involvement and coordinated police enforcement. There are still issues, though, such as corruption and a lack of funding for law enforcement. The protection of India's tiger population depends on continued monitoring, increased public awareness, and improved collaboration between stakeholders for these programs to be successful.

Current initiatives to stop tiger trafficking or poaching in India

Given the importance of preserving its declining tiger population, India has started a number of recent steps to fight tiger trafficking and poaching. The Government of India as well as different State Governments have already taken some initiatives to reduce the risks of illegal poaching or trafficking of wildlife animals. The Wildlife Protection Act of 1972, which forbids the shooting and sale of tigers and their parts, is a crucial element. Poachers now face harsher punishments thanks to recent legislation that highlight the government's dedication to strict legal measures[32]. The "Environmental Investigation agency's" (EIA's) Tiger Campaign promotes the breakdown of transnational criminal networks engaged in illicit commerce in order to aid in the rehabilitation of wild tiger populations[31]. Thus, this agency is presenting for better legislation along with the protection of tigers' habitat. In addition to that, this initiative also exposes the role of tiger farming in stimulating demand and thus poaching of wildlife species can be reduced. Apart from that, the "Project Tiger" started in 1973, is one of the most significant programs the Indian government has undertaken to conserve tigers. a thorough conservation effort that seeks to lessen threats to the existence of tigers and preserve their habitats nationwide. This particular initiative has expanded to include more than 50 tiger reserves nationwide³³. In addition to protecting habitat, this program improves anti-poaching patrols by using drones and video traps to track tiger movements and identify poaching activity. In order to guarantee on-the-ground enforcement, the Indian government has also deployed Tiger Protection Force units in a number of reserves. As a result of the effort, India's tiger population has grown by more than 500%[34]. However, the forest department of India, specifically West Bengal is working on several initiatives such as anti-trafficking, and anti-poaching activities. In addition to that the Indian forest department has also focused on strict policies to ensure barring entry of wood collectors, fishermen, honey collectors, as well as other villagers living in these contiguous. Apart from that, these initiatives heavily rely on partnerships with international agencies like the "Environmental Investigation Agency (EIA)" and "non-governmental organizations (NGOs)". Dismantling transnational criminal networks engaged in wildlife trafficking is the goal of the EIA's Tiger Campaign. In order to deter poaching, this partnership encourages intelligence sharing, improved training for law enforcement personnel, and community awareness campaigns. Additionally, Campaigns to raise public awareness are also essential for altering attitudes regarding tiger conservation. The goal of social media, educational initiatives, and community workshops is to draw attention to the significance of tigers' protection and the negative effects of trafficking. On the other hand, local communities are empowered to take an active role in tiger protection through programs like Community-Based protection. These initiatives seek to lessen the local population's dependency on poaching by offering alternate sources of income and raising awareness of the tigers' ecological significance.

CONCLUSION

In the end of the entire review, it can be concluded that widespread poaching and wildlife trafficking, which are motivated by the demand for tiger body parts both domestically and internationally, pose a serious danger to India's tiger population. Illegal operations continue despite strict regulations and substantial conservation efforts, compromising the efficacy of established restrictions. To counter these risks, strong legislative frameworks, increased enforcement, and community involvement are crucial. Project Tiger and other initiatives have showed potential, but in order to address the underlying causes of poaching, more work must be done to priorities local economic development and education. Based on the findings of this overall review, it has become clear that tiger population is in danger because of high rates of illegal poaching and trafficking across the country. Due to this reason, it is essential to take effective and strict legal initiatives to reduce the risks of tiger and overall wildlife trafficking. In this context, in terms of identifying high-risk locations and create focused solutions, researchers and conservationists must work





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together to share data. Similar to the terrible outcomes of Sariska and Panna, numerous tiger reserves may suffer grave consequences if prompt and concerted action is not taken. To secure the survival of this iconic animal, protecting India's tigers necessitates a multipronged strategy that incorporates community engagement, rigorous enforcement, and sustainable development. However, in order to share and analyse data, this calls for the cooperation of numerous scholars from around the nation. Finding high-risk poaching locations can only aid in lowering the illicit trade by raising awareness of these locations. This can further help identify the justifications for the tiger poaching by the locals as well as tribal people. The economic and educational standing of the local poachers might be addressed to manage the situation. A portion of the substantial sums of public funds that India spends on tiger conservation needs to be redirected to mitigate this pressing problem. Moreover, it can be suggested that authorities need to take extra precautions to shield tigers from illegal trafficking and poaching. If it does not, many tiger reserves of India can resemble Sarika and Panna, where several tigers were slaughtered.

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Isolation and Characterization of Triphenylmethane Decolorizing Bacteria

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ABSTRACT

Synthetic dyes persist in the environment due to their recalcitrant nature and hence have to undergo efficient treatment before being released in the environment. This study aimed at isolating and characterizing potential triphenylmethane dye degrading bacteria from soil sample contaminated with textile effluent. Primary screening was done by plate assay containing bromocresol purple. Isolates showing prominent zone of clearance were selected for secondary screening by broth assay in mineral salt medium (MSM). Optimization of parameters such as dye concentration, temperature and pH for dye decolorization was done. Maximum decolorization of 75.24% was observed at 37°C and pH 8 after 72 hours of incubation. Decolorization efficiency of the immobilized cells was investigated further by immobilizing the isolate in calcium alginate beads. Based on the preliminary characterization, 16S rRNA sequencing and phylogenetic analysis the isolate was identified as *Nesterenkonia* sp., a halo-alkaliphilic bacteria. Phytotoxicity studies on the germination of the seeds of *Vigna radiata* indicated that dye degradation metabolites obtained do not have any inhibitory effect.

Keywords: Triphenylmethane dye, Bromocresol purple, Decolourisation, *Nesterenkonia* sp., Immobilization, Phytotoxicity.





INTRODUCTION

Synthetic dyes have a wide range of applications in industries and clinical setups. These dyes are favoured over natural dyes for properties such as steadfast colour, easy availability and economic feasibility[1]. However, the application of synthetic dyes is also accompanied by environmental issues due to their recalcitrant nature. Synthetic dyes are synthetic aromatic organic coloring agents that are soluble in water, where the basic structure is mostly comprised of carcinogenic compounds like benzidine and other aromatic compounds[2, 3]. Application of the dyes in various industries leads to the entry of dyes into the environment through wastewater. Dyes tend to remain in the environment due to their recalcitrant nature and are resistant to degradation by factors like light, water and oxidising agents [4, 5]. Most of the wastewater treatments for dye removal are physicochemical treatments, which are less effective owing to the complex molecular structure of synthetic dyes, waste produced and the cost [6, 7]. Biological methods have also been adopted for dye containing wastewater treatment and have been found to be advantageous due to the cost, decreased production of sludge and production of products compatible with the environment [8, 9]. Biological processes degrade the complex compounds by mineralising organic contaminants without producing any toxic components [10]. The present study was carried out to screen and isolate triphenylmethane dye degrading efficient strain of bacteria from industrial wastewater.

MATERIALS AND METHODS

The soil sample was collected from effluent contaminated site in the vicinity of local textile industry in Yelahanka, Bengaluru Karnataka, India. After collection, the soil sample was serially diluted and stored at 4°C. Bromocresol purple (BCP) was procured from Himedia India. Stock solutions of BCP of one mgmL⁻¹ concentration were prepared by dissolving in cold sterile distilled water, autoclaved and stored in a brown bottle at room temperature for further use. Modified mineral salt medium (MSM) was prepared as per Ayed *et al.*, (2010) [11]. MSM was prepared by the addition of the following components (gL⁻¹): NaCl (1), CaCl₂·2H₂O (0.1), MgSO₄·7H₂O (0.5), KH₂PO₄ (0.1) and Na₂HPO₄ (1). Nutrient broth and nutrient agar were used for culture maintenance.

Primary screening and characterization of the dye decolorizing bacteria

Isolation of the dye degrading organism was carried out using spread plate technique for the serially diluted soil samples by plate assay method [12]. The isolates were grown in nutrient agar containing BCP dye. The plates were incubated at 37°C for 24-48 hours and were then observed for colonies showing zone of clearance indicating the dye decolorization. They were then picked and further purified by streaking. The selected isolate was further subjected for preliminary identification tests including Gram staining, biochemical test and colony characterization. Biochemical tests and Gram staining procedures were performed [13].

Secondary screening

Secondary screening by broth assay in MS medium containing BCP dye was initially done using smaller volume of the samples. The isolated bacterial strain was allowed to grow in 25 mL MSM broth by using BCP as the sole source of carbon and nitrogen. Uninoculated MS broth incorporated with the dye was used as the control. All the sets were run in six replicates. After incubation the culture was centrifuged at 10,000 rpm for 10 minutes and the bacterial cells were pelleted down, and a clear supernatant was obtained. The absorbance of the clear supernatant was measured by monitoring the absorbance at the maximum absorption wavelength (λ_{max}) at 580nm for BCP using an UV-Visible Spectrophotometer (UV-1700PharmaSpec).

Decolourization (%) was calculated using the following formula [14]:

$$\text{Decolourization (\%)} = \frac{(\text{Initial OD} - \text{Final OD})}{\text{Initial OD}} \times 100$$





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Optimization of temperature and pH for dye decolorization

For optimization of dye concentration, two concentrations were selected. In the first experimental setup the optimization study of dye concentration was done by adding 500 μL of dye in 50 ml of MSM (0.05%). In the second setup the concentration of dye was reduced to 0.025% by adding 250 μL in 50ml MSM. The decolourization assay was carried out at three different temperatures i.e. 30°C, 37°C, and 40°C under shaking conditions to evaluate the optimum dye decolorizing activity of the isolate 1. This assay was performed in 6 replicates. The flasks were incubated for 120 hrs and thereafter checked for decolourization by measuring the absorbance at 580nm in UV- vis spectrophotometer. The decolourization assay was carried out at pH 7, 7.5, 8 and 8.5 under shaking conditions to determine the optimum pH for decolourization of the isolate 1. This assay was performed in 6 replicates. The flasks were incubated for 72 hrs and thereafter checked for decolourization by measuring the absorbance at 580nm in UV- Vis spectrophotometer.

Immobilisation of the isolate and screening of the efficiency for dye decolorization

Immobilization of the dye degrading bacterial isolate was carried out in 2% sodium alginate [15]. The bacterial cell pellet was mixed with 10 mL of sodium alginate which was later suspended in chilled 0.1M calcium chloride solution. Uniform sized beads with the entrapped bacterial isolate were used at the rate of 15 per culture flask containing solutions of pellet and supernatant obtained after centrifugation. They were incubated at 37°C in the shaker incubator for 72 hrs. Control was kept with 15 sodium alginate beads without the bacteria to rule out the possibility of bead matrix efficiency in degrading the dye by adsorption process. After incubation, absorbance was measured using UV visible spectrophotometer at 580nm. The result obtained was then compared with plate and broth assays. The inoculum in the nutrient broth was centrifuged at 6000 rpm for 12 mins. The pellet was resuspended in the phosphate buffer and sonication was done for 20 minutes at 37°C to obtain lysate. The supernatant and the lysate were subjected to fractionation by ammonium sulphate precipitation by stirring on ice. Ammonium Sulphate precipitation was done separately for the cell free extract 1 (extracellular) and 2 (intracellular) obtained after centrifugation of the assay broth. Precipitation was achieved at 80% ammonium sulphate fraction. It was seen that the extracellular supernatant showed higher and faster precipitation than the intracellular supernatants. The precipitate was obtained after centrifuging at 10,000 rpm for 20 minutes at 4°C. The precipitated proteins in the pellet were resuspended in 50mM phosphate buffer (pH 7). The resuspended ammonium sulphate precipitates were desalted by dialysis. Boiling of dialysis membrane (MWCO- 10KD) for 20 minutes in sterile distilled water was carried out to activate the membrane. It was then placed in sterile distilled water and refrigerated until further use. Dialysis was done against 50mM phosphate buffer (pH- 7) for overnight. Then the dialyzed samples – lysate and supernatant were transferred into sterile vial for SDS- PAGE. The molecular weight of the samples obtained after the ammonium sulphate precipitation was determined by SDS – PAGE.

Phytotoxicity studies

The phytotoxic effect of the dye before and after decolorization by microorganism was assessed by using *Vigna radiata* [16]. Twenty seeds each in petri plate placed on the sterile circular filter paper were observed for germination and growth. The experimental set up consisted of seeds treated with dye (1mgmL⁻¹) and seeds treated with degraded sample of dye. Control consisted of seeds allowed to germinate in presence of water. The length of plumule and radicle was recorded after 48 hours and 72 hours respectively and the percentage of germination was recorded.

Antibiotic sensitivity of the isolate to antibiotics

Disc diffusion method was followed to test the sensitivity of the isolate to the antibiotics [17]. The zone of inhibition was measured around each disc. The antibiotic discs used were of ampicillin (10 μg) and penicillin (10 μg).

Statistical analysis

The decolourisation experiments in this study were conducted in six replicates. The findings were reported as mean and standard deviation. Bar graph was plotted along with standard error.



Gowri Subramanian *et al.*,**Molecular identification of the isolate and its phylogenetic analysis**

A16S rRNA sequencing was done for the identification of the isolate. The 16S rRNA sequencing was done by Credora Life Sciences. The nucleotide sequence obtained from the 16S rRNA sequencing was analysed through NCBI BLAST by aligning the homologous sequences. 16S rRNA gene sequence of Isolate1 was submitted in Barcode Biosciences under the reference number 0309_011. The BLAST analysis of the sequence was done.

RESULTS AND DISCUSSION**Primary screening of dye degrading bacteria from the soil sample**

Nutrient agar plates containing bromocresol purple dye showed very few CFU indicating the toxic effect of the textile effluent on the microbial population in the selected soil sample. Several isolates didn't show zones of clearance. Isolate 1 from 10^{-4} dilution showing a zone was selected for secondary screening in mineral salt medium.

Secondary screening

No growth of the isolate was observed on the nutrient agar medium containing a dye concentration of 0.1% and 0.05% indicating that the concentration of the dye was inhibiting the growth of the bacteria. However, at a lower concentration of 0.025% in MSM the bacteria showed better tolerance. Therefore, this concentration was used for further experimental procedures.

Decolorization (%) of BCP by the isolate 1 at different temperatures

The decolourisation ability of the isolate 1 was studied at different temperatures namely, 30°C, 37°C, and 40°C in MSM (pH 7). The decolourization percentage was calculated from the decolourisation percentage formula. The values were confirmed using the standard graph (Fig. 1) and similar values were obtained. Isolate 1 showed maximum decolourisation ($54.52 \pm 8.64\%$) at 30°C when incubated for 120 hours followed by 37°C (51.56 ± 3.42) and 40°C ($49.06 \pm 1.65\%$) as shown in table 1. As illustrated in the figure 2 there is a decrease in the ability of the IS 1 to degrade the dye with the increase in the temperature. It was observed that *Nesterenkonia lacusekhoensis* EMLA3 degraded methyl red at the temperature range of 30°C - 35°C. No changes were seen at 15° C and 50° C [18]. In a Similar study by Prabhakar *et al.*, where reactive violet 1 dye was degraded by *Nesterenkonia* strain at the optimum temperature range of 25° C to 35° C [19]. The microbial growth and the enzyme activity are influenced by the incubation temperature [20]. It was observed that the optimal temperature for the growth of *Nesterenkonia lacusekhoensis* sp. isolated from Antarctica was 25°C – 33.5 °C [21]. The degradation of the dye increases with the increase in the temperature to a particular limit [22]. But at high temperatures, inactivation of enzymes takes place resulting in decrease in the dye degrading ability of the strain [23].

Decolorization (%) of BCP by the isolate 1 at different pH

pH is a significant parameter in wastewater treatment especially in case of biological wastewater treatments [7]. The decolourisation percentage of the dye was calculated after 72 hrs of incubation at pH 7, 7.5, 8, 8.5. As illustrated in table 2, maximum degradation ($75.24 \pm 2.27\%$) was observed at pH of 8.0 followed by pH 7.0, 7.5 and 8.5 when incubated for 72hrs. The figure 3 indicates that the isolate has maximum decolourisation potential at an alkaline pH. A study by Bhattacharya *et al.*, (2017) regarding the removal of azo dye methyl red by *Nesterenkonia lacusekhoensis* showed that optimum pH range required for decolourization was 8-11.5 [18]. Reduction in the pH of the media was also observed after the dye degradation. There were no changes when the pH was adjusted to pH 13. In a similar study by Prabhakar *et al.*, (2019) it was observed that with the increase in pH from 8, there was an increase in the decolourization of reactive violet 1 dye by *Nesterenkonia* strain [19]. It was observed that the optimal pH for the growth of *Nesterenkonia lacusekhoensis* sp. nov., isolated from Antarctica was 8.6 [21].

Preliminary identification of isolate 1

The Gram staining and microscopic observation showed isolate 1 as a Gram-positive short rod. Several Gram-positive rods have been shown to possess dye degrading property [18]. The results of IMViC test showed that the





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isolate gave positive result for only citrate test indicating that the isolate can use citrate as a source of carbon. Negative results were observed for urease test and gelatin hydrolysis test. The isolate when tested for starch hydrolysis showed a positive result as a clear zone was seen around the growth which indicates the production of amylase. It is found that amylase is produced by *Nesterenkonia* sp.. A study on a halophilic bacterium *Nesterenkonia* sp demonstrated the presence of a stable alpha amylase [24]. Similar results were obtained in a study by Li *et al.*, (2008) on *Nesterenkonia halophila* [25]. The isolate gave positive results for catalase test characterised by the appearance of bubbles due to the breakdown of hydrogen peroxide into oxygen and water. Similar results were found by Collins *et al* where *Nesterenkonia lacusekhoensis* tested positive for catalase test [21]. Li *et al.*, (2008) described. The characteristics of *Nesterenkonia alba* which showed catalase positive [25]. A study on *Nesterenkonia natranophila* also showed similar results [26].

Screening of the dye decolorization by the immobilized isolate

The highest decolorization percentage of around 61% was seen in the sample treated with the immobilized beads made from the supernatant as mentioned in table 3 and figure 4. Immobilised amylase enzyme showed maximum decolorisation of azo dyes at pH 8 [27]. In another study, laccase produced by *Bacillus subtilis* was immobilised on chitosan beads for the degradation of indigo carmine and malachite green. The results showed that immobilised laccase was able to decolorise 95.24% indigo carmine and 90% malachite green [28]. Immobilised *Pseudomonas guariconensis* in calcium alginate beads has increased decolorisation ability when compared to free cells [29].

Spectral analysis of the decolorized dye products

Shift in the peak from the visible range to UV range was observed during the spectral analysis of the decolorized sample indicating the degradation of the BCP dye into metabolites. As is evident from Figure 5, the absorption maxima (λ_{max}) of BCP were determined using UV-Visible Spectrophotometer (UV-1700 PharmaSpec) in the UV and visible range (400 – 700 nm). The dye gave a purple shade when dissolved in water. The maximum absorbance was detected by the peak in UV-Visible spectrum at 580nm. A shift in the peak to the range of 200nm-300nm was observed confirming the degradation of the dye.

Partial purification and determination of molecular weight of the dye decolorizing enzyme

Based on the bands formed on the SDS-PAGE as shown in Figure 6, the molecular weight of the enzyme was estimated by comparing with the protein marker. The molecular weight of the enzyme depicted as the prominent band was estimated to be of approximately 40 KDa. Correlating the molecular weight of the band obtained to the enzyme molecular weight reported by Bharagava *et al* it can be assumed that the degrading enzyme could be lignin peroxidase with a molecular weight of ~ 40-45 KDa [30].

Evaluation of toxicity of the degraded dye sample on plants

The treated dye samples were further assessed to study their toxic effect on plants (*Vigna radiata*). Phytotoxicity studies help in examining the detrimental effects of dye containing effluents on the plants. In this study the phytotoxicity of dye before and after degradation was assessed on *Vigna radiata* and the results were tabulated (Table 4). Phytotoxicity studies help in examining the detrimental effects of dye containing effluents on the plants. In this study the phytotoxicity of the dye before and after degradation was assessed on *Vigna radiata*. Germination of seeds was observed in seeds treated with dye decolorized metabolite sample as well as non-decolorized dye. After day 3, inhibition in the germination of the seeds treated with the dye was observed whereas the radicle of the seeds grown in metabolites extracted after decolorisation showed significant growth as shown in Figures 7, 8 and 9. The germination percentage was the highest in seeds treated with decolorized dye metabolites as illustrated in the Table 4. The phytotoxicity results indicated that the metabolites produced on microbial degradation of dyes are non-toxic to the plant growth. Earlier study conducted by Parshetti *et al.*, (2006) showed that germination of *Triticum aestivum* was more when treated with degradation product of malachite green as compared to the non-degraded dye [31]. Similarly other study done by Ayed *et al* (2011) revealed that degradation products are less toxic on the growth of *Sorghum bicolor* and *Triticum aestivum* [32].



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Evaluation of antibiotic sensitivity of the isolate

The increasing antibiotic resistance of microbes is an emerging threat to public health. Wastewater system harbours a diverse community of microorganisms some of which are antibiotic resistant bacteria and are also source of antibiotic-resistant genes [33]. Hence it is important to determine antibiotic sensitivity of the microorganism before its application in waste water treatment. The isolate obtained was tested for sensitivity to antibiotics against ampicillin and penicillin. Clear zones of inhibition were observed suggesting that the antibiotics used inhibited the growth of isolate 1. The zone of inhibition was found to be 50.9mm for ampicillin and 45.9mm for penicillin respectively. This rules out the antibiotic resistance of the isolate and hence there is no threat of its application in any wastewater treatment.

Molecular identification of the isolate and its phylogenetic analysis:

16S rRNA gene sequence of Isolate 1 was submitted to Credora Lifesciences for analysis. The BLAST analysis of the sequence was done. The BLAST sequence exhibited 100% similarity with *Nesterenkonia* sp. MK818807.1. Through phylogenetic analysis, isolate 1 was identified as *Nesterenkonia* sp. strain ADL055 (Figure 11).

Isolate-1: *Nesterenkonia* sp.

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>IL1-16sFP.ab1GGGCGCAGCCTGATGCAGCGACGCCGCGTGCGGGATGACGGCCTTCGG
GTTGTAAACCGCTTTCAGCAGGGAAGAAGCTTTTGTGACGGTACCTGCA
GAAGAAGCGCCGGCTAACTACGTGCCAGCAGCCGCGTAATTAA
>IL1-16sRP.ab1ACCGTCACAAAAGCTTCTCCCTGCTGAAAGCGGTTTACAACCCGAAG
GCCGTCATCCCGCACGCGCGCTCGCTGCATCAGGCTTGCGCCCATTGTG
CAATATTCCCCACTGCTGCCTCCCGTAGGAGTAC
```

Application of microorganisms for the bioremediation of synthetic dyes has been found to be great value to the environment as the method is eco-friendly and cost effective. In this study bacterial isolate *Nesterenkonia* sp. from effluent contaminated soil showed great potential in the decolourisation of bromocresol purple. The results from this study indicate that maximum decolourisation of bromocresol purple was obtained at alkaline pH 8 at 37°C. Further, phytotoxicity studies on the germination of *Vigna radiata* showed that the degraded dye metabolites had no inhibitory effects on the germination of seeds. Antibiotic sensitivity experiments revealed that the isolate was inhibited by antibiotics. Hence any risk of bacterial antibiotic resistance that could pose a threat in handling the isolate is ruled out. Moreover, there are no reports about its pathogenicity. Immobilization of cells and enzymes can be efficient tools in dye decolourisation. Immobilization experiments showed that higher decolourisation percentage was observed in sample treated with immobilised beads prepared from supernatant. Further work can be done in purifying the enzymes secreted by *Nesterenkonia* sp. degrading bromocresol purple and immobilising the same to achieve greater results. *Nesterenkonia* has a great potential for its application in industries for the treatment of dye effluents since it is a halophilic bacterium that can tolerate a high salt concentration usually present in textile effluents.

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Table.1:Decolourization (%) of BCP dye at different temperatures in MSM (pH 7)

SAMPLE	INCUBATION TIME (Hours)	TEMPERATURE (°C)	% DECOLORISATION
Isolate 1	120	30	54.52 ± 8.64
		37	51.56 ± 3.42
		40	49.06 ± 1.65

Mean ±SD; n=6

Table.2: Decolourization % of BCP dye at different pH

SAMPLE	INCUBATION TIME (Hours)	pH	% DECOLORISATION
Isolate 1	72	7.0	72.6 ± 1.92
		7.5	70.87 ± 3.04
		8.0	75.24 ± 2.27
		8.5	67.60 ± 5.84

Mean ± SD; n=6

Table.3: BCP decolorization % by the immobilised isolate 1 at 37°C

SAMPLE	INCUBATION TIME (hr)	TEMPERATURE (°C)	pH	DECOLORISATION %	
Isolate 1	120hrs	37 °C	8	Pellet	56.07 ± 6.54
				Supernatant	61.37 ± 7.26

Mean± SD; n=6



Gowri Subramanian *et al.*,Table.4: Phytotoxic analysis of BCP dye and the decolorized dye samples against *Vigna radiata* seeds

Treatment	Radicle Length (cm)		Germination Percentage	
	48 Hours	72 Hours	48 Hours	72Hours
Control (Distilled water)	0.26±0.23	0.46±0.32	55%	55%
Degraded Dye Metabolites	0.44±0.30	0.66±0.41	42%	62%
Dye Stock (1mgmL ⁻¹)	0.81±0.72	0.89±0.76	50%	55%

Mean ± SD; n=6

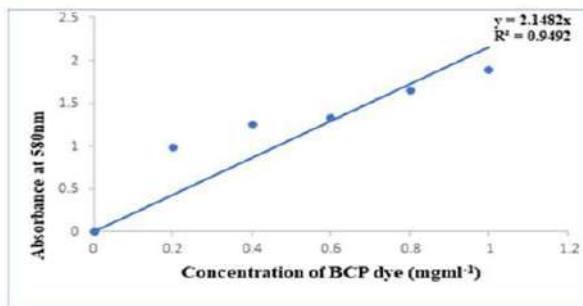


Figure.1: Standard graph for BCP

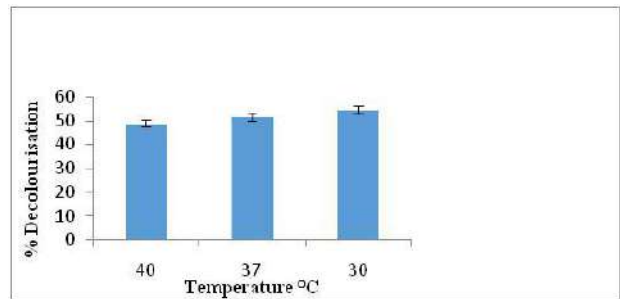


Figure.2: Decolorization % of BCP by isolate 1 at different temperatures in MSM(pH 7)

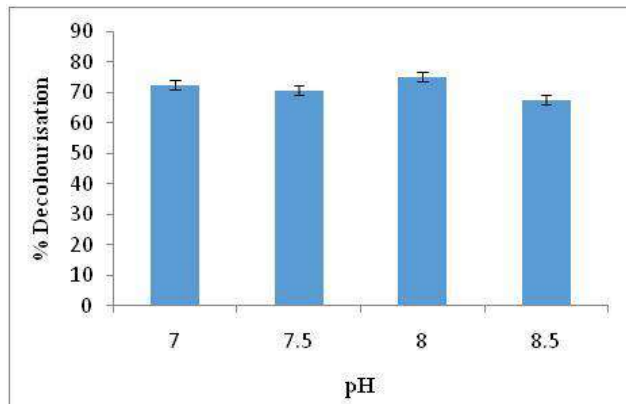


Figure.3: Decolorization % of BCP by isolate 1 at different pH in MSM at 37°C

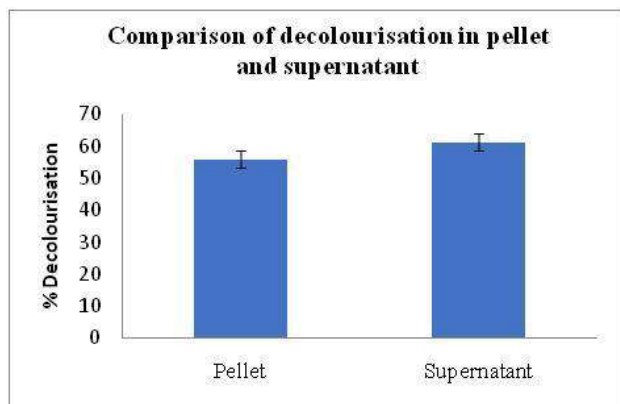


Figure.4: Comparison of decolourization percentage in pellet and supernatant



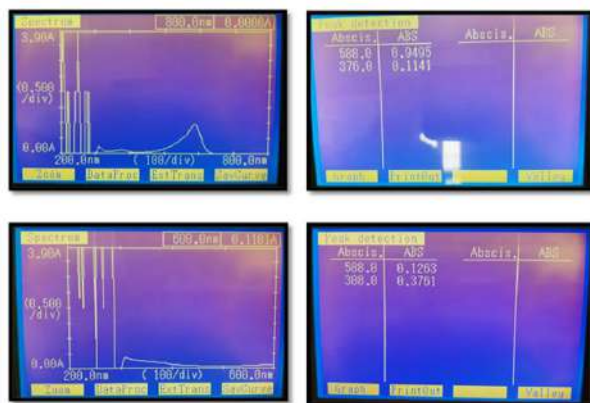


Figure.5: Shift in the spectrum observed in the decolorized sample

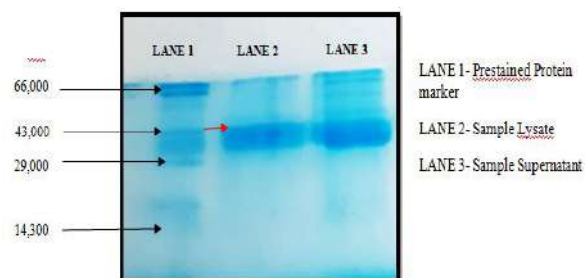


Figure.6: Molecular weight determination of lignin peroxidase enzyme by SDS-PAGE

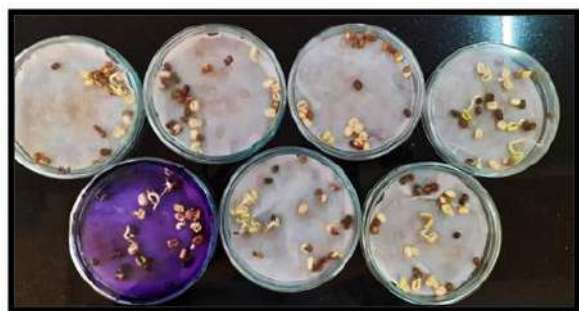


Figure.7: Phytotoxic analysis for each decolorized sample of BCP dyes against *Vigna radiata* (72 hrs): 1- Control (D/W); 2,3,4,6 and 7 - Decolorized dye samples; 5 - Dye stock (1 mgL⁻¹)



Figure.8: Phytotoxic analysis for each decolorized sample of BCP dyes against *Vigna radiata* (120hrs): 1. Control (d/w) –Untreated seeds; 2. Seeds treated with dye; 3. Seeds treated with metabolites of decolourized dye sample; 4. Seeds treated with decolourized dye sample



Figure.9: Germination of *Vigna radiata* with the treated dye sample

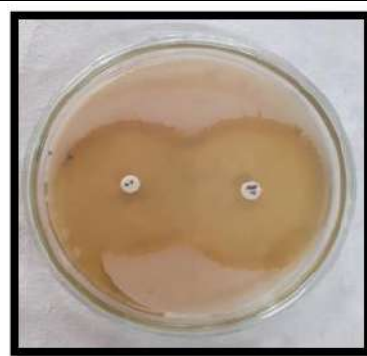
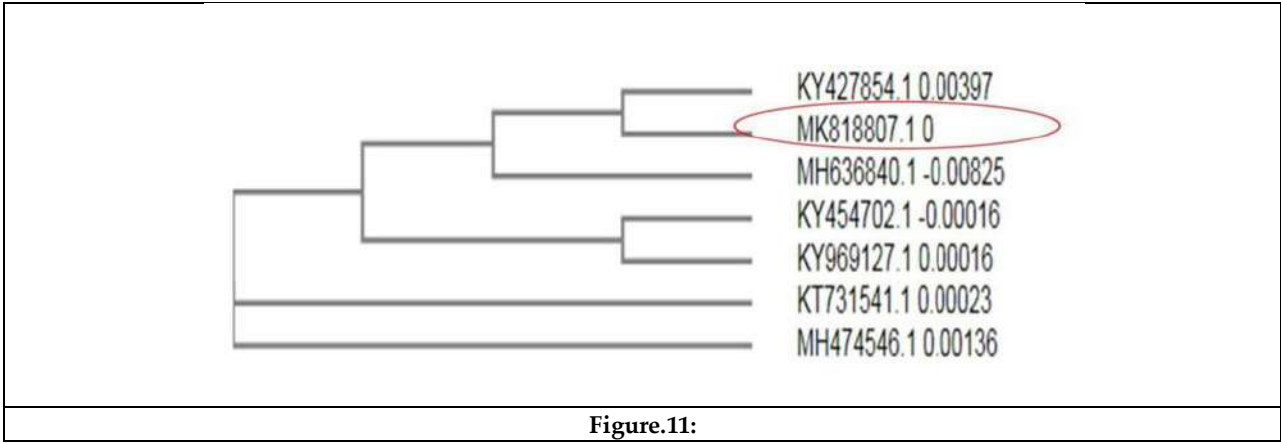


Figure.10: Suppression of isolate 1 by antibiotics ampicillin and penicillin.





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A Study on Knowledge of Pineapple Growers under the Recommended Package of Practices in Cultivation in Manipur State

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ABSTRACT

An important commercial crop in Manipur, the pineapple (*Ananas comosus*) generates significant farm income and economic stability. The Manipur Organic Mission Agency (MOMA) has undertaken a number of projects to improve pineapple output through the establishment of efficient marketing infrastructure and the promotion of scientific growing techniques. The purpose of this study was to evaluate the growers' knowledge and determine the elements that affect them. By using a proportionate random sampling study design, a sample of 300 respondents was chosen from three districts in Manipur. The results show that the majority of respondents had a medium level of knowledge, with high and low knowledge groups follows. Each respondent possessed extensive knowledge about various techniques, including propagating plants using suckers, choosing soil and locations with moderate slopes, spacing plants in a single row system (75 x 30 cm), utilizing rainfed irrigation, manually pulling weeds to prevent pests and diseases, harvesting plants at a mature but green stage for the neighborhood market, cleaning for post-harvest handling, identifying plants according to size, shape, maturity, and disease-free status, packing using bamboo baskets and jute sacks, and applying conventional storage techniques.

Keywords: Knowledge, Organic, Pineapple, Manipur.



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INTRODUCTION

Ananas comosus, or pineapple, is one of the most significant commercial crops in the world (Hossain, 2015). It is also one of the most popular fruits consumed worldwide because of its unique flavor and fragrances (Maia et al., 2020). With a share of almost 8% of the world's pineapple production, India comes in sixth place globally (Priyanka Roy & Souvik Ghosh, 2022). The pineapple became known as the Manipur state fruit on the 12th of June 2009 (E Pao, 2009). It is grown in almost every district of the state. Pineapples are the primary source of income for many farmers (Das et al., 2019). It is known as a cash crop in Manipur. In terms of business, growing pineapples has become a major income source for many farmers. Pineapple's growth in Manipur has the potential to become a major industry that creates a lot of jobs and income. Kew and Queen Pineapples are the main types grown in Manipur. In the state, pineapples are significant fruit crops that are produced in large quantities for eight months out of the year (Rabina et al., 2021). 30% to 40% slopes are ideal for cultivation due to steeper slopes might cause excessive soil erosion in the wet season and insufficient moisture retention in the winter. Because of its susceptibility to hilly terrain, the Queen variety is mainly grown in the districts of Thoubal and Imphal East (T. Chanu, 2014). In Manipur's hill regions, where pineapple farming is a significant source of income, financial service providers operating under the Manipur Organic Mission Agency (MOMA) along with other related agencies have been supporting pineapple farming communities.

To support and promote pineapple production, MOMA's intervention initiatives have provided farmers with necessary farming supplies and marketing platforms in partnership with partner business agencies. The Department of Horticulture and Soil Conservation, Manipur, reached a remarkable accomplishment in July 2022 when they shipped 20 metric tons (MT) of fresh, ripe, organic pineapples to Dubai for the first time. The Manipur government's Directorate of Horticulture and Soil Conservation noted the achievement in a survey that was conducted in 2022 (Imphal Free Press, 2022). Manipur's actual pineapple production averages 21.56 tonnes per hectare, a figure that is less than the estimated yield of 40–50 tonnes per hectare. A lack of adoption of contemporary farming techniques, such as high-density planting, efficient fertilizer management, skilled weed control, and sustainable farming practices-particularly in hilly terrain with suitable soil conservation measures is the cause of this gap. Marketing pineapples effectively is one of the biggest problems Manipur's pineapple growers confront. Regarding the newest advances in pineapple growing, many farmers are ignorant. This can be resolved by putting in place a strong extension program that informs farmers about the newest techniques for growing pineapples and promotes their adoption. According to Roy et al. (2013), farmers will find it easier to adopt new farming technology if they are introduced through an intense extension system and regularly scheduled training programs. The purpose of this study is to determine how much knowledge pineapple growers in the state of Manipur have about scientific cultivation practices.

METHODOLOGY

The state of Manipur was selected for this investigation due to its well-known status as one of India's primary pineapple-growing regions. The investigation was conducted in three districts that had a high density of pineapple growers. A proportionate random sample technique was used to select 300 respondents in total. A pre-tested organized schedule and in-person interviews were used to acquire data. The ICAR Research Complex for NEH Region Manipur Center, Lamplalpat, Imphal, proposed pineapple cultivation procedures, and this was the study's main focus. The respondents' knowledge was divided into three categories using cumulative frequency methods: low, medium, and high. Frequency and percentage were utilized to examine the knowledge levels.

RESULTS AND DISCUSSION

The data regarding the practices-wise knowledge of recommended technologies in pineapple cultivation are present in Table 1.



**Nongmaithem Gyaneshor Singh et al.,****Improved variety**

It is divided into two different pineapple varieties, Queen and Kew, compared to the suggested enhanced varieties. The findings indicate that respondents had a very high level of knowledge about these types. The majority of participants are acquainted with both the Queen and Kew types. Compared to the Queen variety, which has an awareness rate of 97.7%, the Kew variety has a slightly higher rate of 98.7%. Despite the fact that both types are well-known, this little variation suggests that pineapple growers in the area might prefer the Kew variety more. 98.2% of respondents, on average, are aware of both suggested variations. This indicates that growers in Manipur's have efficiently received information about enhanced pineapple cultivars, leading to nearly universal

Method of Propagation

The data provided shows the following about the different ways pineapple is propagated, such as Ratoons, Suckers, Slips, and Crown: Since all responders (100%) are aware of the Suckers approach, it is the most well-known and probably the one that farmers employ the most frequently. The Ratoons (83.0%) and Slips (87.7%) approaches are similarly well-known, however not as widely accepted as Suckers, according to a sizable portion of respondents. Only 3.3% of respondents, in contrast, were aware of the Crown technique, indicating that producers in the area either do not support it or do not see it as extensively marketed. The average awareness of all approaches is 68.5%, which suggests that respondents have a typically moderate understanding of the various dissemination strategies.

Treatment of Sucker

The investigation indicates that respondents understood very little about Panchagavya (8.7%) and Amritpani (4.0%) treatments. This suggests that growers of pineapples in the area are not well-informed about or using these treatments. The average awareness rate for these sucking treatments is 6.35%, indicating that respondents generally know very little about these particular techniques. Results show a critical knowledge gap about sucker treatments and emphasize the need for better agricultural extension and related educational programs.

Selection of Suitable Soil/Site

The fact that all respondents (100%) agree that moderate slopes are best for growing pineapples shows that producers fully comprehend and accept this site selection criterion. The majority of respondents (94.3%) had knowledge that hill areas are appropriate for pineapple farming, indicating that this information is widely disseminated and acknowledged. In contrast to mild slopes and hills, plain sites can also be appropriate, as indicated by the knowledge of just over half of the respondents (57.7%), indicating a lack of agreement or information regarding this fact. The average awareness rate for all site selection criteria is 84.0%, suggesting that although specific site characteristics, such as hills and moderate slopes, are well known, there are general gaps in thorough understanding of various site types. The information presented here emphasizes the need to improve our knowledge of the general suitability of sites for pineapple production.

Land preparation

In regarding land preparation methods for pineapple growing, almost all respondents (99.3%) have knowledge of the trenches method, which suggests that growers are aware of this technique and probably use it frequently. A sizable portion of respondents (66.0%) are also aware of the raised beds method, which suggests that although growers are aware of this approach, a sizable portion may not be familiar with it. The average awareness percentage of land preparation procedures among the respondents is 82.65%, indicating an average level of knowledge. This analysis shows that while there is a high level of awareness about some approaches, there is a need to increase knowledge about all suggested practices to guarantee that all pineapple growers are well-informed and capable of using these strategies.

Times of Planting

Almost all respondents (97.7%) understood that April to May is the best season to plant when it comes to pineapple production, indicating that growers are aware of this recommendation and frequently follow it. Significantly more respondents (75.0%) are aware that the months of June through August are ideal for planting, suggesting that this



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time range may not be as well-known or extensively advertised by extension services. There is a moderate overall level of knowledge regarding the optimal planting periods, as seen by the average awareness percentage of 86.35% for planting times. Although most people are aware of the April–May planting season, it can still be successful to cultivate if the benefits and recommended practices for this time of year are emphasized.

Spacing

All respondents (100%) are aware of the Single row system (75×75 cm) when it comes to spacing techniques for growing pineapples, suggesting it is the most well-known and probably the most frequently employed technique among producers. A moderate level of awareness regarding the Double row system ($60 \times 90 \times 60$ cm) is shown by the fact that less than half of the respondents (46.3%) are familiar with it. The High-density planting ($35 \times 75 \times 35$ cm) approach is the least known among growers, since only 25.0% of the respondents are aware of it. A moderate overall understanding of the various spacing approaches is shown in the average awareness percentage of 57.1% for all spacing methods. According to this data, even though everyone is familiar with the single-row approach, more needs to be learned about other efficient spacing techniques. Raising knowledge of these techniques may aid in increasing planting density and yield optimization.

Fertilisers

A significant portion of respondents (87.3%) aware of Farmyard Manure (F.Y.M.) when it came to the usage of different fertilizers for pineapple cultivation, suggesting that it is a well-known and frequently utilized fertilizer among pineapple growers. The fact that a sizable percentage (73.7%) are familiar with urea suggests that it is also widely utilized and understood. A considerable amount of familiarity with Single Super Phosphate (S.S.P.) is indicated by the fact that just over half of the respondents (53.3%) are aware of it. Only one-third of respondents (33.3%) were aware of the use of muriate of potash (M.O.P.), and only 26.7% of respondents were aware of micronutrients. These two topics have the lowest levels of awareness. This suggests that there remains much to learn about the significance and practical uses of micronutrients. The average knowledge percentage for all types of fertilizers is 54.86%, suggesting that respondents have a moderate level of general comprehension. This information highlights the necessity of focused instructional programs to increase pineapple growers' understanding of fertilizer use, which could increase fertilizer efficiency and increase crop yields.

Irrigation

It is evident that depending on rainfall is a widely known technique and probably a standard practice for pineapple growers in the area, as all respondents (100%) are aware of the rainfed irrigation method. It is evident that growers have a moderate level of awareness and potential use of sprinkler irrigation, as more than half of the respondents (56.0%) are familiar with it. With regard to surface and sub-irrigation techniques, slightly more than half (50.7%) have some awareness of them, indicating a reasonable level of understanding. More formal or systematic irrigation techniques are likely less common, as seen by the fact that fewer than half (43.7%) of respondents are aware of the general irrigated method (possibly implying methods other than rainfed, sprinkler, or sub-irrigation). The average awareness percentage of all irrigation techniques is 62.6%, indicating that respondents had a reasonable level of knowledge about different irrigation systems overall. According to this investigation, pineapple growers should become more knowledgeable about alternative efficient irrigation techniques in order to improve water management and possibly boost crop output, even though rainfed irrigation is widely known.

Weeding and hoeing operations

Almost all respondents (98.0%) were aware of the guideline of carrying out weeding and hoeing operations four times, which suggests an extensive amount of knowledge and probably widespread adoption of this frequency among growers. Significantly more (73.3%) are aware of the advice to carry out these procedures twice, indicating moderate familiarity with this less common practice. About weeding and hoeing activities, the average awareness percentage is 58.65%, indicating a moderate level of general understanding regarding the appropriate frequency. In order to maximize cultivation practices and enhance crop results, it is imperative that pineapple growers get ongoing and focused education regarding the optimal frequency of weeding and hoeing.



**Nongmaithem Gyaneshor Singh et al.,****Weed Control**

The fact that every respondent (100%) knows about the hand-weeding technique suggests that pineapple growers are generally aware of it and probably use it frequently. The mechanical weeding method is known to slightly more than half of the respondents (50.7%), indicating an average degree of familiarity and possibly limited utilization among producers. A comparable percentage of participants (54.3%) acknowledge their familiarity with the chemical weeding technique, implying that although it is fairly well-known, its application may be less extensive than that of hand weeding. The average awareness rating for all weed management techniques is 68.33%, indicating that respondents generally know a moderate to high amount about different weed control strategies.

Pest and disease management

With regard to various methods of controlling pests and diseases, all respondents (100%) know how important it is to use good planting materials in order to prevent rot diseases, suggesting that producers might be experienced in this activity. A reasonable level of awareness of this preventive practice is indicated by the fact that about half of the respondents (52.3%) are aware of how important proper drainage is in preventing various rot diseases. There is a notable lack of awareness about Mealy bug wilt and the recommended methods for managing it, as just 9.0% of respondents were aware of them. Furthermore, not a single responder (46.6%) understood that defoliation sprays or treatments may be used to manage rot diseases, indicating a complete lack of awareness or application of this chemical control strategy. Because adopting healthy planting materials is widely known to be important, the average awareness percentage for all pest and disease management approaches is 51.8%, showing a generally reasonable degree of knowledge.

Harvesting

That every respondent (100%) knows about the practice of collecting mature but still green pineapples for the local market suggests that growers are certainly familiar with and frequently use this technique. Regarding harvesting pineapples at 75–80% maturity for distant markets, about half of the respondents (51.0%) are aware of this practice, indicating a modest level of knowledge and maybe limited implementation among growers. There is a notable knowledge gap for this particular harvesting technique, as just 9.3% of respondents are aware that pineapples can be harvested for embankment when they are between 1/2 and 3/4 yellow. The average awareness percentage of all harvesting activities is 53.43%, indicating that respondents have a moderate understanding of the suggested harvesting methods overall.

Yield

Regarding the expected yield of pineapple, a considerable segment of participants (63.3%) knows about the expected production range of 50-80 tonnes per hectare. This suggests that growers possess a moderate degree of awareness regarding the output potential of pineapple under ideal circumstances. Even though the amount of awareness is moderate, it can still be raised. The main goal of education should be to guide growers on the elements - such as appropriate cultivation techniques, disease and insect control, and sufficient fertilization-that can contribute to reaching the ideal yield range of 50–80 tonnes per hectare.

Aftercare of Ratoon Crop

Desuckering is a well-known and probably commonly used aftercare technique for ratoon crops, as indicated by the large majority of respondents (84.3%) who were aware of it. The practice of fertilization and earthing up after desuckering is, however, only 34.3% known to the respondents, indicating a substantial knowledge gap with this particular aftercare procedure. A usually modest degree of knowledge is reflected in the average awareness percentage of 59.3% for ratoon crop aftercare practices among the respondents.

Post-harvest management

Cleaning harvested pineapples is one of the post-harvest management activities that all respondents (100%) are aware of, indicating that growers likely engage in this commonly known and practiced post-harvest activity. The pre-cooling method, which helps preserve pineapple quality and improve its shelf life, is well-known to a sizable



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majority (76.7%) of respondents. Furthermore, the majority of participants (93.3%) indicated that they are aware of the post-harvest drying of pineapples, indicating that drying is a common procedure that lowers moisture content and guards against spoiling. An overall high level of knowledge regarding appropriate post-harvest activities is shown in the average awareness percentage of 90.0% for all post-harvest management practices among respondents.

Grading

All responders (100%) are aware of the standards for grading pineapples, which include size, shape, maturity, and lack of diseases or flaws. This suggests that grading is a commonly understood concept and probably a common practice among producers. This information emphasizes how crucial it is to provide ongoing training to pineapple growers so they can reliably use efficient grading techniques and raise the produce's quality and market value.

Packaging and Transport

The majority of respondents (100%) know that growers generally follow and are generally aware of the suggested packing techniques, which include utilizing jute sacks, bamboo baskets, crates lined with paddy straw, and other materials. It is also suggested that these transport strategies are also widely understood and used because all respondents (100%) are aware of the suggested modes of transportation, which include head load, cartload, trucks, and tractors. An overall high degree of knowledge regarding these post-harvest practices is seen in the average awareness percentage of 100% for packaging and transport techniques among respondents.

Storage

All of the respondents (100%) are aware of common storage techniques shows that producers generally accept and are familiar with this essential technique. A sizable majority (83.0%) are aware of cold storage techniques, indicating a high degree of awareness of this innovative method that can increase pineapple shelf life. About 17.3% of respondents, however, were aware of the use of ethereal treatment for uniform ripening, indicating a notable lack of knowledge about this particular post-harvest technique that can improve the uniformity and quality of ripening. The average awareness rating for all storage procedures is 66.76%, indicating that respondents generally know a moderate to high amount about efficient storage techniques.

Processing

Slightly more than half of the respondents (61.0%) are aware of methods like producing syrup, juice, and jam regarding the recommended processing processes for pineapples, demonstrating a moderate level of knowledge among the growers regarding these value-added approaches. Growing pineapples for syrup, juice, and jam offers growers a great opportunity to teach them about the benefits, as 39.0% of respondents were unaware of these processing methods. This can boost profitability, cut waste, and help them diversify their product line. The findings emphasize how crucial it is to provide ongoing training and assistance to pineapple growers so they may become knowledgeable about different efficient processing techniques, which will allow them to increase the value of their produce and boost overall profitability. From table 2 inferred that a significant proportion of pineapple growers surveyed (67.7%) demonstrated a medium overall knowledge level, suggesting a reasonable understanding of relevant agricultural practices and techniques. A considerable number of respondents (20.3%) reported a high overall knowledge level, indicating potential gaps in understanding key aspects of pineapple cultivation and management. A smaller yet noteworthy segment (12.0%) exhibited a low overall knowledge level, indicating a strong grasp of agricultural knowledge and potentially advanced skills in pineapple cultivation. Efforts should focus on enhancing the overall knowledge level of pineapple growers, particularly among those demonstrating low or medium levels of knowledge. Collaboration with agricultural experts, research institutions, and experienced farmers can provide valuable insights and support in disseminating best practices and advanced techniques to improve overall knowledge levels among pineapple growers.





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CONCLUSION

From the findings, it can be concluded that the majority of respondents had a medium level of knowledge followed by high and low knowledge groups. While awareness remains high in certain areas, there are notable knowledge gaps in others. In order to maximize production and boost profitability, growers of pineapples must be adequately informed about all facets of cultivation, post-harvest handling, and value addition.

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Table.1. Practical wise Knowledge on recommended technologies in pineapple cultivation (n=300)

Sl. No	Practices	Responses	
		No. of respondents	Per cent
1	Improved variety:		
	Queen	293	97.7
	Kew	296	98.7
	Mean Percentage	98.2	
2	Method of propagation:		
	Ratoons	249	83.0
	Suckers	300	100
	Slips	263	87.7
	Crown	10	3.3
	Mean Percentage	68.5	
3	Treatment of Sucker:		
	Amritpani	12	4.0
	Panchagavya	26	8.7
	Mean Percentage	6.35	



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4	Selection of Suitable Soil/Site		
	Plain	173	57.7
	Moderate slope	300	100
	Hill	283	94.3
	Mean Percentage	84.0	
5	Land preparation:		
	Raised beds cm high & 150 cm wide)	198	66.0
	Trenches of 20 ×30 cm across the slope (Maybe dug above after every 3 rows)	298	99.3
	Mean Percentage	82.65	
6	Times of Planting:		
	April - May	293	97.7
	June – August	225	75.0
	Mean Percentage	86.35	
7	Spacing:		
	Single row system 75 × 75 cm	300	100
	Double row system 60 ×90 ×60 cm	139	46.3
	High density planting 35 ×75 × 35 cm	75	25.0
	Mean Percentage	57.1	
8	Fertilisers:		
	F.Y.M: 25 tons/ha	262	87.3
	Urea: 36 g/plant	221	73.7
	S.S.P: 25 g/ plant	160	53.3
	M.O.P: 75 g/plant	100	33.3
	Micro Nutrients	80	26.7
	Mean Percentage	54.86	
9	Irrigation:		
	Sprinkler irrigation	168	56.0
	Surface and Sub-irrigation	152	50.7
	Rainfed	300	100
	Irrigated	131	43.7
	Mean Percentage	62.6	
10	Weeding and hoeing operations:		
	2 times	220	73.3
	4times	294	98.0
	Mean Percentage	58.65	
11	Weed control:		
	Hand weeding	300	100
	Mechanical weeding	152	50.7
	Chemical weeding	136	54.3
	Mean Percentage	68.33	
12	Pest and disease management:		
	Mealy bug wilt: (dipping of planting materials in 0.02 – 0.04% Ekatox before planting and Thimat 10 gm @ 17.5 kg/ha after planting)	140	46.6
	Leaf rot, Base rot, Fruit rot, Black rot or Soft rot, Heart rot, Steam rot and Leaf spot etc.		



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	Good drainage	157	52.3
	Healthy planting materials	300	100
	Spray of Defoliation or Captain	25	8.3
	Mean Percentage	51.8	
13	Harvesting:		
	Green but mature for the local market	300	100
	75-80% maturity for distant market	153	51.0
	1/2 – 3/4 yellow colour for embankment	28	9.3
	Mean Percentage	53.43	
14	Yield:		
	i) 50-80 tonnes/hacter	190	63.3
15	Aftercare of ratoon crop:		
	Desuckering	253	84.3
	Fertilisation and earthing up after desuckering	103	34.3
	Mean Percentage	59.3	
16	Post-harvest management:		
	Cleaning	300	100
	Pre-cooling	230	76.7
	Drying	280	93.3
	Mean Percentage	90.0	
17	Grading:		
	Size, Shape Maturity and free from diseases and blemishes	300	100
18	Packaging and transport:		
	Jute sack/ bamboo basket/ crates/ line with paddy straw etc.	300	100
	Transport by heat load/cart load/lorries/tractor	300	100
	Mean Percentage	100	
19	Storage:		
	Ordinary	300	100
	Cold Storage	249	83.0
	Ethereal treatment of uniform ripening	52	17.3
	Mean Percentage	66.76	
20	Processing:		
	(syrup, juice, jam)	183	61.0

Table.2. Overall knowledge level of pineapple cultivation practices (n=300)

Sl. No	Category	Frequency	Percentage
1	Low	36	12.0
2	Medium	203	67.7
3	High	61	20.3
	Total	300	100.0





The Effect of Bowen Technique and Neurodynamic Sliders to Promote Flexibility in Hamstring Tightness in Asymptomatic College Students

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ABSTRACT

The beginning of a new training schedule or significant increases in workout volume are frequently linked to the development of hamstring strain. Hamstring tightness is commonly correlated with good health. Young adults (18-25 years old) enrolled in college often report having tight hamstrings. This study suggests that the neuro dynamic sliders approach and bowen therapy are the two ways to increase hamstring flexibility. According to this study, either the bowen treatment or neurodynamic sliders are more effective at increasing hamstring flexibility. Experimental study was done. A total of 60 college students with asymptomatic hamstring tightness have been selected according to the criteria for inclusion and exclusion. They have been split into two groups, The bowen technique group (n = 30) and a neurodynamic sliders group (n = 30). Both the intervention were given for three weeks, three sessions per week in alternating days. Passive straight leg raise (PSLR) and the active knee extension test (AKE) was used to evaluate the subjects. Goniometer is used to measure ROM. According to the statistical analysis, The paired and unpaired t test were used to analyse the values. The pre and post test values were analysed by using PSLR and AKE in both groups. The mean value of bowen technique group was found to be more significant than the neurodynamic sliders technique with p value is <0.0001 The result suggests that bowen technique shows a significant improvement in increasing hamstring flexibility and ROM than neurodynamic sliders.

Keywords: Hamstring muscle, range of motion, muscle tightness, college students, muscle stretching Exercise.



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INTRODUCTION

There is a traditional term for the fatty and muscular region behind the knee, called the "ham." The term "hamstrings" refers to the tendons that feel like strings on either side of the back of the knee. The hamstring's medial group consists of the semitendinosus and semimembranosus muscles, while the lateral group is made up of the long and short heads of the biceps femoris, which together create this two-joint muscle structure. The short head is the only portion of the biceps femoris muscle that does not extend the hip and knee joints.[1] Most people who have tight hamstrings are in good health.[2] More women (45%) than men (27.50%) experience hamstring tightness. Exercise causes the release of endorphins, or "feel-good hormones," which reduce dysmenorrhea symptoms.[3] To treat hamstring tightness, There have been several methods employed in the past, including spray, muscular energy technique (MET), soft tissue mobilization technique, and stretching exercise.[4] For athletes with ITB tightness, IASTM and FR methods greatly increase the advantages of exercise.[5] Flexibility can be impacted by how tight certain soft tissue components, joint capsules, muscles, and fascia are about one another.[6] One of the main reasons why healthcare workers become unwell is because of work-related musculoskeletal disorders (WRMSDs); similarly, Asymptomatic hamstring tightness is a common issue among college students, often resulting from prolonged sitting, poor posture, or a lack of regular stretching. Despite the absence of pain or noticeable discomfort, this tightness can impact flexibility and muscle function over time. Given the numerous studies conducted on hamstring tightness, it is essential to concentrate on a patient-reported outcome.[7] In addition to its primary effect on the person experiencing hamstring muscle stiffness, which may or may not cause pain, it can limit functional activities and quality of work performed by the workers. Although hamstring injuries have no single known cause, a number of variables, such as age, ethnicity, poor running form, insufficient flexibility, muscle weakness, and an imbalance in muscular strength, may be involved.[8] Information from college students who started their courses online is provided by a survey. These late-night internet activities lead to sleep disturbances, prolonged exposure to smartphones and computers, and late-night sleep. Individuals with an evening mentality are more likely to experience mental health issues they also tend to maintain sedentary lifestyles, which can cause weakness and tightness in their muscles.[9] The onset of neuromusculo skeletal disorders and limited range of movement. The connective tissue that envelops muscles is called myofascial tissue. It helps transmit force, gives the muscles structural support, and permits flexibility and mobility of the muscles throughout the body.

When it is injured, inflamed, or inactive, it can diminish strength and endurance and limit ROM.[6] Although the absolute lengths of the hamstring muscles varied by gender, these variations did not correspond to variations in the proportions of femur length.[10] The paraspinal and hamstring muscles exhibited a moderate to strong connection, and the SWE modulus of all the muscles rose significantly after submaximal hamstring contractions.[11] In a range of motion (ROM), the hamstring muscles are used to control human mobility such as sprinting, jumping, forward bending while seated or standing, and various postural control exercises.[12,13] For postural balance, hamstring muscle flexibility is essential, full maintenance of the extent of mobility in the knee and hips, injury prevention, and optimal musculoskeletal function, especially in the field of rehabilitation.[14] People won't be able to carry out basic daily tasks that call for bending at the knee or extending at the hips without sufficient hamstring flexibility.[15] Among the most widely recognised reasons for injury to the hamstring appears to be inadequate flexibility inside the posterior thigh compartment.[16] The tibial, sciatic and common fibular nerves altered neurodynamics may be the cause of reduced flexibility in the hamstrings, as shown by the passive straight leg raise test (PSLR) restricted range.[17] It's possible that changes in the neurodynamics of the posterior lower extremities could impact resting muscle length and change how someone experiences pain or stretch. The flexibility of the hamstring muscles in the back of the leg, thigh, buttock, and spinal canal may be affected by the mechanosensitivity of the brain regions. Because of hamstring tension and the accompanying risk of strain injury, protective muscle activation of the hamstring muscles may be responsible for neural mechanosensitivity.[18] The hamstring muscle group was outstripped and innervated by self-stretching, which was combined with neurodynamic sliders. The only treatment used was Bowen to increase hamstring extensibility. In this research, we evaluate the impacts of the Bowen technique and neurodynamic sliders to promote flexibility in hamstring muscle tightness.



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MATERIALS AND METHODS

According to inclusion criteria, the study participants were selected from the physiotherapy OPD at the private multi-speciality hospital, Chennai, Tamil Nadu, India. Participants who were college students without symptoms of hamstring tightness, both genders aged between 18 and 25, subjects with a positive Supine SLR test, active 20–50 degree reduction of knee extension while the hip is 90 degrees flexed, and dominant right lower limb were included. Individuals experiencing both neurological and low back discomfort, individuals who have experienced a lower extremity injury within the last three months, any fracture or surgery performed on the knee, hip, pelvis, or back, hamstring injuries, hypermobility of the lower limb joint, and muscle imbalance of the lower limb were excluded in this study. The study used a sample of 60 college students with asymptomatic hamstring tightness. It was an experimental study conducted among college students with asymptomatic hamstring tightness. The study used a random allocation technique to divide the groups with a convenient sample. Materials required for this study was universal double-arm goniometer. The total duration of this study was three weeks. These treatments were administered to both groups three times a week on different days. Subjects from both the bowen technique group and the neurodynamic sliders group participated in the pre-test evaluation and The outcome of the investigation were then assessed using the active knee extension test (AKE) and the passive straight leg raise (PSLR). A universal goniometer is used for ROM measurement. The official approval from the Institutional Scientific Review Board with the ISRB number(01/029/2023/ISRB/SR/SCPT).

bowen technique group (30)

On the plinth, The patient is lying down on their back. Lift the leg to a 90-degree angle; the therapist should grip the ankle while performing the initial exercise with the same hand's elbow. Place a couple of fingers below the sit bone and make a first move[19]with the biceps femoris at the middle of the semitendinosus and semimembranosus muscles. Make a lateral slack, press in, and perform a medial move on the midline of the hamstring muscles, a few inches below the sit bone. The second move is to place your thumb behind in the popliteal fossa. The therapist should next hold your ankle and move it erratically. Then, give your foot a firm tap to activate your hamstrings. Apply pressure over the hamstring muscle and the thumb should hooked onto the lateral edge.[20] The muscle begins to contract, plop, or react in some other way when we start to place our thumb down in a medial direction. The fingers should move from the left side of the body toward the right side. On alternate days, three sessions per week, the intervention was administered, and each session took 20 minutes.

neurodynamic sliders group (30)

The "Seated Straight Leg Slider" (SSLS), was executed by participants. To perform this sliding technique, participants had to seated in slump position (both lumbar and thoracic flexion), which they were required to keep up during the workout. In this seated straight leg sliders, the movements were alternated between knee flexion and ankle plantar flexion, which resulted in a decrease in neural tension followed by knee extension and ankle dorsiflexion, which resulted in an increase in neural tension, combined with cervical extension, which resulted in a decrease in neural tension.[21]

outcome measures

At baseline, an assessment was carried out (before starting treatment) and Using the active knee extension test (AKE) and passive straight leg raise (PSLR), three weeks into the study period. The active knee extension test (AKE) measures the length of the hamstrings and looks for potential hamstring contractures. It is also known as the 90-90 hamstring test. The knees are extended until they are parallel to the ground, and the opposing arm is elevated until the hip forms a 90-degree angle. Any extension less than 20 degrees is seen as hamstring tightness, while a 20-degree lag is considered normal from full extension. The AKE test is used to measure hamstring length, detect hamstring stiffness, and determine whether hamstring contracture may be present. A basic physical examination method for individuals experiencing lower back pain and discomfort is the Lasague test, also referred to as the straight leg lift test or the passive straight leg raise (PSLR). Participants with normal hamstring flexibility can achieve 80° or more in that test, while those with tight hamstrings can only reach less than 80°.





RESULTS

The PSLR and AKE tests indicate a significant reduction in hamstring tightness post-examination, suggesting improved flexibility or muscle relaxation compared to prior measurements. This decrease in tightness could imply effective treatment or alleviation of muscle strain. These results indicate improved hamstring flexibility and mobility. The decrease in tightness suggests increased muscle length and reduced stiffness after the intervention.

Table-1 Compares the Bowen technique group's pre- and post-test values in PSLR, The pre-test's mean(41.9), SD(6.09). In contrast, $t=22.707$, the post- test mean(44.6), SD(6.1). the P-value is less than 0.0001, the results are considered highly significant. However, compares the Neurodynamic sliders group's pre- and post-test values. The pre-test's mean(39.2), SD(6.16). On the other hand, $t=14.252$ and the post-test mean(40.9) and SD(6.25), respectively. the P-value is less than 0.0001, it means that the results are very statistically significant.

Table-2 Compares the post-test results for the Neurodynamic sliders group and the Bowen technique group in PSLR. The results show that the mean value for the Neurodynamic sliders group(40.9), SD(6.25), $t=2.318$, whereas the mean value for the Bowen technique group(44.6), SD(6.11). When the P-value = 0.0002, the results are considered to be statistically significant.

Table-3 The Bowen technique group's pre- and post-test values in AKE. The Post-test mean value(39.2), SD(5.08), and $t=25.938$. The pre-test mean(36.6), SD(5.06). the P-value is less than 0.0001, the findings are very statistically significant. However, compares the Neurodynamic sliders group's pre- and post-test values. The pre-test's mean(34.4), SD(4.22). In contrast, $t=13.857$, the post-test mean(35.6), SD(4.26). Very statistically significant outcomes are shown by P-values less than 0.0001.

Table-4 Post-test results for the Neurodynamic sliders group and the Bowen technique group in AKE. The mean value for the Neurodynamic sliders group(35.6), SD(4.26). $t=2.974$, whereas the mean value for the Bowen technique group(39.2), SD(5.08). p value=0.0043. The results are considered statistically significant. This shows that, when compared to the neurodynamic sliding technique, the bowen technique yields more functional benefits.

DISCUSSION

Experimental comparison of the Bowen's effects and neurodynamic sliding techniques on flexibility in asymptomatic college students with tight hamstrings is the aim of the current study. In this study, 60 subjects with asymptomatic hamstring tightness were selected, and PSLR and AKE tests were used as outcome measures to mark pre-test values. Values of before and after the treatment were tabulated. The goniometer is the material required to determine ROM. According to a study by Michelle Marr that examined hamstring flexibility over time as a result of the approach, although the superficial pressure used during the procedure invalidates changes caused by tissue slide due to stress or tissue plastic deformation, there is no bearing weight, warming up, stretching, or joint loading associated with it.[15] This research's findings show the significance of the Bowen technique and neurodynamic sliders on promoting flexibility in hamstring tightness in asymptomatic college students in terms of flexibility and the extent of movement. The hamstring flexibility and ROM have been evaluated using AKE and PSLR tests. A statistically significant difference between the groups was revealed by the current investigation's results ($p<0.001$) and a difference that is statistically significant was found for both approaches in terms of improving hamstring flexibility for between-group analysis; the p value for the Bowen technique group is equal to 0.0002, which is considered statistically significant. Given that the p value for the neurodynamic sliders group is 0.0043, it is considered statistically significant. Roel de Ridder, et al. In individuals with decreased flexibility, This was the initial investigation to examine the effects of a neurodynamic intervention plan that lasted 6 weeks at home on the flexibility of the hamstrings in comparison to a static stretch.[21] All patient's hamstring flexibility increased significantly as a result of both therapies, surpassing the MDC of 3.18° , but with a significantly greater gain in flexibility of the hamstrings (12.6° versus 9.3°), our outcomes significantly demonstrated what could be beneficial of employing neurodynamic sliders superior to the conventional



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approach, supporting the hypothesis of our study.[22]The sciatic nerve can be linearly extended using neurodynamic sliders.[23]which might avoid or alter these adhesions, resulting in a decline in the mechano sensitivity of neurons and an increase in the visco elasticity of neurological tissue, which would promote hamstring mobility.[24]Small lesions in the hamstring muscle might progressively reduce stretch tolerance, particularly during explosive eccentric loading at the end range. If left untreated, this may increase the risk of strain injuries in the hamstring. Malliaropoulos et al. (2004) continued to follow eighty Greek athletes who had been diagnosed with second-degree hamstring injuries. In rehabilitation, sliders may offer the best solution since they primarily increase the mobility and mechanical function of the nerve within the mechanical interaction with minimal neural pressure.[25]The effects of bowen therapy on hamstring tightness are investigated in this study in asymptomatic college students, and significant improvement has been achieved in terms of hamstring flexibility.[18]The AKE test was used as a hamstring flexibility measuring technique.[25] Thus, our research determined that when applied alternately for three sessions, the bowen technique and the neurodynamic sliding technique both have similar efficacy in improving the range of motion and flexibility. To help individuals with hamstring tightness, both methods can be utilized therapeutically to improve flexibility and ROM.According to our research, We determine that both the neurodynamic sliding technique and the Bowen techniqueimprove flexibility of hamstring muscle and ROM. The study found significant improvements in hamstring flexibility and functional outcomes following the Bowen technique intervention, particularly in asymptomatic college students. Future research can be conducted over longer time periods. A similar study could be expanded with a large number of sample. The bowen and neurodynamic sliding procedures can also be used to operate with other muscles. These results align with current research supporting the bowen method's benefits. The technique shows potential for enhancing functional outcomes and hamstring flexibility. However, To validate these results and evaluate long-term impacts, more investigation and long-term monitoring are required.

Abbreviation

range of motion (ROM),passive straight leg raise(PSLR), active knee extension test (AKE)

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Table 1: Comparison between the pre-test and post-test values of bowen technique group and neurodynamic sliders

PSLR (ROM)		MEAN	SD	T-VALUE	P –VALUE
BOWEN TECHNIQUE GROUP	PRE-TEST	41.9	6.09	22.707	< 0.0001
	POST-TEST	44.6	6.11		
NEURODYNAMIC SLIDERS GROUP	PRE-TEST	39.2	6.16	14.252	
	POST-TEST	40.9	6.25		

Compares the pre and post-test values of bowen technique group, The mean value of the pre-test is 41.9 and the SD value is 6.09, Where as the post-test mean value is 44.6,SD value is 6.1, $t = 22.707$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 and Compares the pre and post-test values of neurodynamic sliders group, The mean value of the pre-test is 39.2 and the SD value is 6.16, Where as the post-test mean value is 40.9,SD value is 6.25, $t = 14.252$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001.

Table 2: Comparison between the post-test values of bowen technique group and neurodynamic sliders group in PSLR.

PSLR (ROM)		MEAN	SD	T-VALUE	P-VALUE
BOWEN TECHNIQUE GROUP	POST- TEST	44.6	6.11	2.318	p = 0.0002
NEURODYNAMIC SLIDERSGROUP	POST- TEST	40.9	6.25		

Compares the post-test values of the bowen technique group and neurodynamic sliders group, revealing that the mean value of the bowen technique group was 44.6 and SD value is 6.11, whereas the neurodynamic sliders group mean value was 40.9 and SD value is 6.25, $t = 2.318$. As a result, the findings are considered statistically significant when the p-value is equal to 0.0002.

Table 3: Comparison between pre-test and post-test values of bowen technique group and neurodynamic sliders group in AKE.

AKE (ROM)		MEAN	SD	T -VALUE	P -VALUE
BOWEN TECHNIQUE GROUP	PRE-TEST	36.6	5.06	25.938	< 0.0001
	POST-TEST	39.2	5.08		
NEURODYNAMIC SLIDERS GROUP	PRE-TEST	34.4	4.22	13.857	
	POST-TEST	35.6	4.26		





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Compares the pre and post-test values of bowen technique group. The mean value of the pre-test is 36.6 and the SD value is 5.06, Whereas the post-test mean value is 39.2, SD value is 5.08. $t = 25.938$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 and Compares the pre and post-test values of neurodynamic sliders group. The mean value of the pre-test is 34.4 and the SD value is 4.22, Whereas the post-test mean value is 35.6, SD value is 4.26, $t = 13.857$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 .

Table 4: Comparison between the post-test values of bowen technique group and neurodynamic sliders group in AKE.

AKE (ROM)		MEAN	SD	T-VALUE	P-VALUE
BOWEN TECHNIQUE GROUP	POST-TEST	39.2	5.08	2.974	P = 0.0043
NEURODYNAMIC SLIDERSGROUP	POST-TEST	35.6	4.26		

Compares the post-test values of the bowen technique group and neurodynamic sliders group, revealing that the mean value of the bowen technique group was 39.2 and SD value is 5.08, whereas the neurodynamic sliders group mean value was 35.6 and SD value is 4.26, $t = 2.974$. As a result, the findings are considered statistically significant when the p-value is equal to 0.0043.



Fig.1 bowen technique The therapist uses hands, fingers, and thumb in this technique to roll gently in short strokes over the flesh's muscles, tendons, ligaments, and nerves in hamstring muscle.



Fig.2 Neurodynamic sliding technique The patient in slump position performing alternating movements between knee flexion and ankle plantar flexion followed by knee extension and ankle dorsiflexion 3 sets of 20 repetitions.





EARAA – A Machine Learning Approach to Energy Optimization in 5G and IoT Networks

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ABSTRACT

The expansion of wireless networks, driven by 5G, IoT, and forthcoming 6G technology, brings an increased need for energy-efficient solutions to mitigate high power demands, environmental strain, and operational costs. This study systematically addresses these challenges, focusing on cutting-edge energy-saving strategies for wireless communication. We reviewed recent literature from key databases including Google Scholar, IEEE Xplore, SCIE, and Scopus, narrowing down relevant studies from 2018 to 2024. Our keyword selection included "Energy Efficiency," "5G Networks," "Machine Learning in Wireless Networks," and "Energy Harvesting in IoT," with rigorous inclusion criteria prioritizing research on power optimization, resource allocation, and adaptive network control. Using a comparative approach, we analyzed a range of techniques, such as machine-learning-enhanced resource allocation, energy harvesting, and adaptive modulation schemes, illustrating findings through flowcharts, tables, and performance graphs. Our results reveal that the proposed Energy-Aware Resource Allocation Algorithm (EARAA), which leverages machine learning to predict network traffic, achieved up to 40% energy savings, boosted throughput by 35%, and lowered latency by 30% over conventional methods. These improvements underscore the suitability of EARAA for applications in high-demand networks like IoT and urban infrastructure. This review provides a fresh perspective by focusing on predictive, machine-learning-based approaches to resource allocation, an area often overlooked in past studies that primarily explored static or isolated techniques. Furthermore, we discuss practical deployment challenges and outline future directions, including field testing and model enhancements. By presenting a detailed comparison of energy-saving strategies, this study offers essential insights and a clear pathway toward more sustainable network management solutions.

Keywords: Energy Efficiency, Wireless Networks, Machine Learning in Wireless Communications, Energy Harvesting, Resource Allocation, 5G and Beyond.





INTRODUCTION

The landscape of wireless communication has rapidly evolved with the development of 5G networks, IoT applications, and the emerging framework for 6G technologies. These advancements have redefined connectivity standards, supporting a broad spectrum of applications in sectors such as smart cities, autonomous systems, and industrial automation. However, the increased demand for constant connectivity and high-speed data transmission has significantly impacted energy consumption. Maintaining efficiency in network operations while minimizing energy usage has, therefore, become an urgent priority to sustain this growth. Current research has contributed valuable insights into energy optimization for wireless networks. For example, [1] developed a regression-based model to enhance energy efficiency in wireless sensor networks by dynamically adjusting power levels based on network load. Although effective, this model focuses on sensor networks and may struggle to accommodate the complexity of more diverse and high-demand applications. [2] took a step further by implementing machine learning to optimize energy usage in NOMA (Non-Orthogonal Multiple Access) systems, focusing on downlink efficiency. However, their approach, while promising, is specific to NOMA environments and lacks scalability across broader network types. Furthermore, [3] explored energy reductions through resource allocation using free-space optics in dense network setups, but this approach does not fully address the need for resource adaptability to manage diverse and dynamic traffic patterns. A significant gap remains in designing a flexible, energy-optimizing strategy that adjusts dynamically to real-time network conditions. The evolving landscape of heterogeneous networks requires adaptable solutions that can provide scalable, real-time resource allocation based on traffic forecasts. The present study addresses these issues by introducing a holistic, predictive approach to energy management.

Research Contributions

This paper introduces the Energy-Aware Resource Allocation Algorithm (EARAA), which integrates machine learning to predict network traffic and adjusts resource allocation accordingly. This approach builds on prior work by offering a flexible, real-time optimization solution that improves energy efficiency across a variety of network conditions. Through simulations, the EARAA method demonstrated up to 40% energy savings, a 35% throughput gain, and a 30% latency reduction over conventional static methods.

Research Gaps

While existing methods offer valuable insights into energy efficiency, most solutions focus on isolated optimizations, lacking a comprehensive, predictive framework. Many studies either address specific network types or employ fixed resource allocation that does not accommodate real-time traffic changes. This limited adaptability fails to address the energy demands of increasingly complex, large-scale, and heterogeneous networks.

Research Questions

This study explores the following research questions:

- How can machine learning models effectively predict network traffic to optimize energy usage in real-time across diverse network types?
- What impact does predictive, adaptive resource allocation have on energy consumption, latency, and throughput in large-scale wireless networks?
- How does the proposed EARAA approach compare to conventional energy optimization methods in terms of efficiency and scalability?

LITERATURE REVIEW

Significant research has been conducted on reducing the energy consumption of wireless networks. Researchers have developed various techniques, including adaptive power control, energy harvesting systems, and machine learning-based solutions. Below, we review key contributions in this area. [1] developed a regression model to enhance energy



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efficiency in WSNs, focusing on energy harvesting based on network load. While promising, this approach is less adaptable for networks with varying traffic demands. [2] applied machine learning to optimize energy in NOMA systems, focusing on downlink energy efficiency. However, its scope is limited to NOMA, reducing its general applicability. [3] used free-space optics to improve energy efficiency in urban networks; however, its application is limited in low-density or rural settings. [5] introduced a coot-based energy management model for WSNs; however, this model is best suited for small-scale networks and not easily transferable to larger systems, such as those used in IoT or 5G. [6] tested wireless power transfer relays, effective in non-cooperative networks but limited in more interconnected, cooperative networks. [7] investigated delay-phase precoding for MIMO in THz frequencies, achieving energy gains but only effective in specific MIMO configurations. [7] explored energy harvesting specifically for 6G networks, demonstrating sustainable energy use in high-density networks but lacking scalability for varied or complex network environments. [8] used machine learning for resource allocation in mobile edge computing, enhancing energy efficiency but at a high computational cost, limiting broader scalability. [9] applied deep learning for fault-tolerant routing in WSNs, tailored to handle network faults but not easily adaptable for high-capacity 5G or IoT networks. [9] developed a fault-tolerant protocol for WSNs, emphasizing reliability, but lacking adaptability for high-traffic network environments. [10] implemented the PTS method for reducing PAPR, which achieves energy savings but is constrained to certain waveform types. [11] utilized multi-hop routing to reduce energy consumption in underwater networks, although its methods struggle to address the dynamic needs of terrestrial network traffic. [14] designed self-organizing ad-hoc networks with machine learning, improving autonomy but lacking the energy metrics required for large-scale applications. [15] investigated battery-less WSN sensors using solar energy, which enhances energy sustainability but relies on solar conditions, limiting wider application. [16] implemented adaptive modulation in dense IoT networks, but may not handle high-speed networks that require rapid modulation changes. [18] evaluated machine learning algorithms for 5G, achieving energy gains but requiring further adjustments to manage high computational demands. [19] employed machine learning for energy harvesting in IoT networks, yet the solution's suitability for larger networks remains untested. [21] studied power control techniques for 5G, but they require frequent recalibration, making real-time application challenging. [23] used AI to optimize IoT network energy use, but the solution has yet to be tested across diverse network configurations. [23]

Studied resource allocation in cognitive radio networks, effective under fixed conditions but limited in dynamic settings. [24] examined dynamic spectrum allocation within 5G networks, though its scope is restricted to fixed network conditions, limiting its flexibility for more varied network types. Dynamic Spectrum and Adaptive Protocols. [24] examined resource allocation for 5G, yielding some energy savings but not fully scalable for 6G or IoT applications. [25] explored power management for drones, suitable for constrained setups but not applicable to larger network configurations. [26] studied energy harvesting for mobile networks, effective but limited for large IoT systems that need varied energy sources. [27] developed an AI-based resource management system for 5G, achieving energy efficiency, but computationally demanding, challenging its scalability. [29] addressed sustainable communication in 6G, providing a forward-looking framework but lacking immediate applications for current networks. [30] researched resource allocation in satellite-terrestrial networks, suitable for integrated systems but lacking adaptability for terrestrial-only networks. [31] proposed adaptive routing to save energy but focused on low-power settings, limiting the approach's utility in more demanding network scenarios. [32] examined routing in WSNs, focusing narrowly on low-power networks, limiting insights for larger, mixed-infrastructure networks. [33] explored adaptive modulation for IoT, improving efficiency for low-density scenarios, but untested for mixed, high-traffic environments. Challenges in Energy-Efficient Protocols. [34] developed a power-saving protocol for high-speed 5G but lacks adaptability for slower, high-density environments. [35] presented a fault-tolerant protocol enhancing network reliability but with limited application in highly variable traffic settings.





METHODOLOGY

The methodology outlines the steps taken to design and evaluate the proposed Energy-Aware Resource Allocation Algorithm (EARAA), detailing the materials used, data sources, criteria for study selection, and the algorithm's development. This section emphasizes a systematic approach to ensuring the reliability and relevance of data used.

Database Selection and Keyword Search

The following academic databases were consulted to review prior studies and establish a foundational understanding of energy-efficient networking methods: IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar. These sources were selected for their extensive, peer-reviewed publications in wireless communication technologies.

1. Keywords Used: Searches included combinations of terms such as "energy-efficient wireless networks," "machine learning in wireless networks," "5G resource allocation," "IoT energy management," and "spectrum management for network efficiency."

2. Year Range: We focused on articles published between 2018 and 2024 to incorporate the most recent advancements in 5G, IoT, and AI-based solutions for network efficiency.

Inclusion and Exclusion Criteria

A set of criteria was applied to select relevant studies, ensuring the inclusion of high-quality and pertinent research. This filtered out articles lacking substantial experimental data or rigorous methodology.

Parameters for Concept Development

The development of the EARAA algorithm centered on optimizing power consumption and network efficiency under variable loads. Several performance metrics were identified as essential to achieving the study's goals, as shown in Table 2.

Required Materials

Hardware Requirements

- High-Performance Computer: To conduct simulation, equipped with:
 - Processor: Intel Core i7 or higher
 - Memory: 16GB RAM minimum
 - Storage: SSD with 500GB for high-speed data processing
 - Router/Modem: Optional if physical network testing is needed.
- IoT Devices: Devices with network connectivity for optional real-world validation, such as:
 - Raspberry Pi or Arduino modules with communication capabilities
 - Power monitoring sensors

Software Requirements

- MATLAB/Simulink: Main software environment for network simulations and EARAA development.
- NS-3 Network Simulator: Used to emulate real-world network environments and assess algorithm performance.
- Python Libraries:
 - TensorFlow or PyTorch for deep learning-based traffic prediction.
 - NumPy for data handling and numerical analysis.

Proposed Algorithm: Energy-Aware Resource Allocation Algorithm (EARAA)

The flowchart in Figure 1 illustrates the logical progression of the EARAA algorithm, from traffic prediction through power adjustment, resource allocation, and performance evaluation.

The EARAA algorithm leverages machine learning to manage resources efficiently by predicting network traffic demand and adjusting power levels accordingly. The following steps outline its core functions:



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1. **Traffic Prediction:** The algorithm begins with predicting upcoming network traffic levels based on past usage patterns. For this, a machine-learning model, specifically the Long Short-Term Memory (LSTM) network, is utilized due to its effectiveness in handling time-series data. Regular updates to the model with recent data allow for accurate, real-time predictions that adapt to dynamic network conditions.
2. **Power Adjustment:** Using the traffic forecasts, the algorithm dynamically adjusts power levels across the network. For periods of high anticipated traffic, power is increased to ensure smooth data flow and prevent potential bottlenecks. Conversely, during expected low-traffic periods, power is decreased to save energy while maintaining baseline connectivity.
3. **Resource Allocation:** The algorithm then allocates essential network resources—like bandwidth, processing power, and other necessary computational resources—based on the predicted demands. This step includes dynamically adjusting spectrum usage to maximize bandwidth efficiency, thereby helping reduce network latency and maintain steady connectivity under varying loads.
4. **Performance Evaluation:** Finally, the algorithm assesses its performance by measuring key metrics such as latency, throughput, and energy usage. By continuously monitoring these metrics, the algorithm can make fine adjustments to ensure optimal energy use without compromising on performance quality.

RESULTS AND DISCUSSION

The results below reflect the simulation outputs of the EARAA algorithm, evaluated under varying load conditions and benchmarked against conventional resource allocation methods. The performance metrics include power consumption, energy efficiency, network throughput, and latency.

Simulation Setup

The MATLAB/Simulink platform was used to conduct simulations over a 10,000-second timeframe, covering a range of network loads. The network model included 5G base stations, Wi-Fi nodes, and IoT devices to simulate real-world, heterogeneous traffic scenarios.

Performance Metrics

The key performance metrics used to assess the EARAA algorithm include: Power Consumption (W) to measure the average network power usage across varying traffic loads. Energy Efficiency (J/bit) to indicate energy required per bit transmitted, allowing for cross-scenario comparison. Network Throughput (Mbps) provides average data transmission rate achieved under each load condition. Latency (ms) to show delay experienced by packets, monitored as an indicator of algorithm responsiveness.

RESULTS

Table 3, Table 4, Table 5, Graph 1 and Graph 2 illustrate the EARAA algorithm's impact on power consumption, energy efficiency, and network performance.

DISCUSSION

The results indicate that the EARAA algorithm provides consistent power savings across all load scenarios, as seen in Table 3 and Graph 1. By dynamically adjusting power levels based on anticipated traffic, the algorithm achieves up to a 30% reduction in energy use for high-traffic situations compared to baseline approaches. As shown in Table 4 and Graph 2, EARAA significantly improves energy efficiency metrics. The energy-per-bit ratio decreased by nearly 40%, demonstrating the algorithm's effectiveness in resource allocation. This improvement is crucial for applications such as IoT and 5G, where energy efficiency impacts both operational costs and environmental sustainability. The algorithm's resource allocation features notably increased network throughput by 35% and reduced latency by 30%, supporting a smoother and faster user experience. This performance boost is critical for high-demand scenarios like



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real-time IoT applications or streaming services, where low latency and high throughput are essential. These findings confirm that EARAA's energy-saving approach is highly beneficial for real-world applications, especially within smart cities, industrial IoT systems, and other environments with dense device deployments. The ability to reduce power costs while maintaining network quality has significant potential for widespread adoption.

CONCLUSION

This paper presents the Energy-Aware Resource Allocation Algorithm (EARAA), designed to address critical energy efficiency demands in modern wireless networks, particularly across 5G, IoT, and potential 6G systems. By utilizing machine learning for predictive traffic analysis, EARAA adjusts power levels and allocates resources in real-time, leading to optimized performance while significantly lowering energy consumption. Through simulations, EARAA has shown substantial improvements across key metrics, including power conservation, network latency, and data throughput, compared to conventional methods. This study enriches the current body of knowledge by combining machine-learning-based traffic forecasting with real-time resource management, offering a comprehensive approach to reducing energy consumption in communication networks. Distinguishing it from prior studies that often focused on singular methods like dynamic spectrum management or energy harvesting, EARAA integrates these approaches into a unified, adaptive framework. By demonstrating up to 40% in energy savings and enhancing throughput by 35%, EARAA contributes a versatile, practical tool for sustainable network management—filling a gap in the research on adaptive, machine-learning-based network resource allocation. While EARAA provides valuable advancements, certain limitations remain. The algorithm was tested in controlled simulations that, while detailed, cannot fully emulate real-world conditions, which often include diverse hardware and environmental variations. Additionally, EARAA's use of machine learning for predictive adjustments introduces a level of computational demand that may not be ideal for lower-power IoT devices. Future studies could explore more lightweight models or decentralized approaches to increase suitability for such resource-limited environments. There is also room to further develop energy-efficient solutions specifically for low-power networks, which would allow EARAA to expand its applicability across even more constrained settings. These results open up various paths for further investigation. Testing EARAA in real-world deployments within 5G and IoT networks would yield deeper insights into its scalability and effectiveness. The integration of EARAA with edge computing and small cell infrastructures would also enable more localized, energy-conscious resource management, with potential benefits across smart cities, industrial IoT applications, and green networking. Additionally, adapting EARAA for multi-access edge computing (MEC) could meet the needs of highly heterogeneous networks, creating a flexible, efficient power management system. Compared to existing approaches, EARAA is a novel blend of predictive traffic analysis with adaptable, real-time resource management, addressing an underexplored area in energy-efficient network design. This work provides a bridge between data-driven forecasting and active resource allocation, areas that have rarely been combined in prior studies. By delivering empirical evidence of power savings and network performance improvements, EARAA offers a promising framework for advancing sustainable, high-performance network solutions in the evolving field of wireless communications.

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Table.1: Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Study Focus	Energy efficiency, resource allocation	Topics outside wireless networking
Publication Type	Peer-reviewed journals, conference papers	Non-peer-reviewed articles
Content Quality	Quantitative analysis, experimental data	Lacks quantitative results or experimental data
Technological Scope	5G, IoT, AI-driven resource allocation	Focus on outdated technologies (e.g., 3G)
Language	English	Non-English
Metrics Reported	Power consumption, latency, throughput	Lacks data on energy or performance metrics





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Table.2: Key Parameters for Concept Development

Parameter	Description
Power Consumption	Measures network power use across varying loads (in Watts)
Energy Efficiency	Calculated as energy consumed per bit of data (Joules per bit)
Network Throughput	Assesses average data rate (in Mbps)
Latency	Measures packet delay across different load conditions (in ms)

Table.3: Power Consumption Under Different Traffic Loads

Network Technology	Low Load (W)	Medium Load (W)	High Load (W)
4G	1.3	2.9	5.2
5G	1	2.4	4.5
IoT Devices	0.5	1.3	2.2
Wi-Fi	1.2	2.7	5.3
NB-IoT	0.4	1	1.6

Table.4: Network Performance Metrics Comparison

Metric	Baseline Approach	EARAA Method
Power Consumption (W)	4.2	3
Energy Efficiency (J/bit)	3.5	2.1
Network Throughput (Mbps)	150	210
Latency (ms)	48	28

Table.5: Resource Allocation Strategies and Impact on Performance

Allocation Strategy	Energy Savings (%)	Latency Reduction (%)	Throughput Increase (%)
Dynamic Spectrum Management	25%	20%	18%
Energy Harvesting	30%	15%	10%
ML-based Resource Allocation	35%	25%	30%
Adaptive Modulation	28%	18%	25%
Power-Aware Routing	32%	22%	20%
EARAA	40%	30%	35%

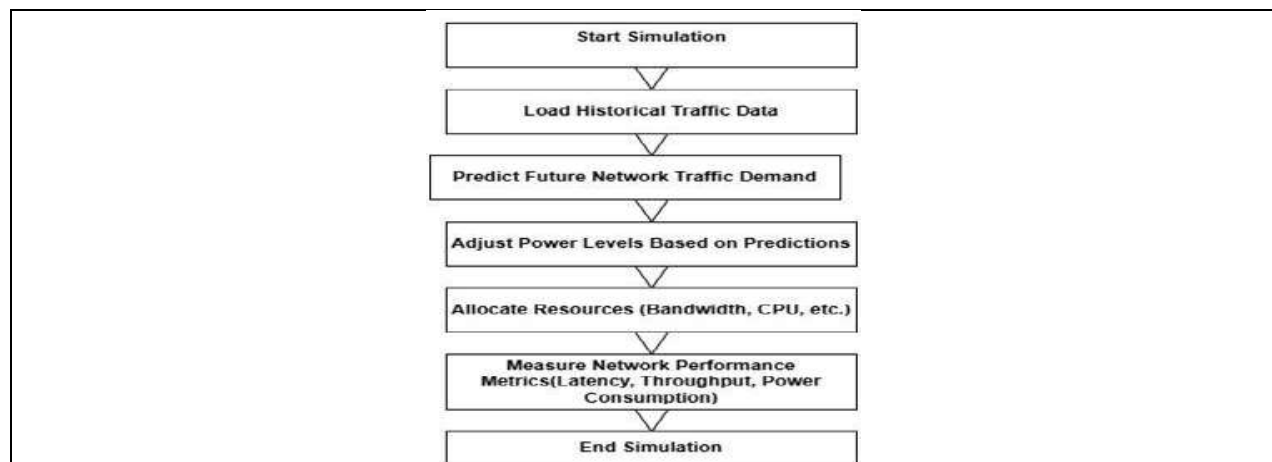
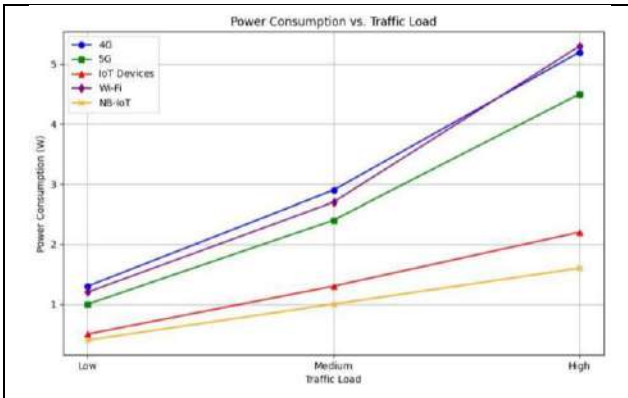


Figure 1: Energy-Aware Resource Allocation Algorithm Flowchart

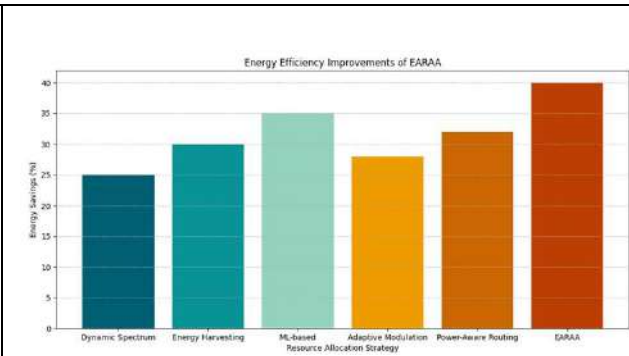




Soumya Roy and Gouranga Bag



Graph.1: Power Consumption vs. Traffic Load



Graph.2: Energy Efficiency Improvements of EARRA





An Astrological Insight on Ayurved

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ABSTRACT

Jyotish is one of the *Vedanga*. *Ayurved* is an ancient system of medicine of India. Roots of both sciences are connected to *Vedas*. *Ayurved* focuses on physical, mental, social, spiritual wellbeing of a person while *Jyotish* provides insights into planets and their effects on one's mind and body. *Jyotish* predicts the possible future outcomes regarding behaviour, mental and physical health status of individual. *Ayurved* believes in prevention of possible diseases and *Chikitsa* (treatment) of patients and besides this, *Jyotish* also provides solutions to improve mental and physical health status through various methods. Through this article, an approach has been made to understand how these sciences - *Jyotish* and *Ayurved* have many similarities between them, are interconnected and can be integrated to gain wellbeing of an individual.

Keywords: *Veda, Jyotish, Ayurved, Prakriti, Daivavyapashraya Chikitsa, Tithi*

INTRODUCTION

According to ancient Indian scholars, *Vedas* form the foundation of Indian culture and are closely connected with the Indian system of medicine. Four *Vedas* existed i.e. *Rigveda*, *Yajurveda*, *Samaveda* and *Atharvaveda*. [1] The word *Veda* is derived from the *Sanskrit* word 'Vid'. [2] Which means Knowledge. [3] *Vedas* are the sacred texts which contain recitation of hymns, performance of rituals, code of social conduct, chanting of songs, and are source of culture, beliefs and customs. *Vedas* have six *Anga*(parts) i.e. *Shiksha*, *Kalpa*, *Vyakarana*, *Nirukta*, *Chhanda* and *Jyotish*. [4] *Jyotish* is said to be the Eye of *Vedapurusha*. [5] Just like one cannot work properly without an eye, same way one cannot achieve





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proper knowledge of *Veda* without *Jyotish*. *Jyotish* is an ancient science which is endowed with knowledge of movement and positions of *Graha*(Planets) and *Nakshatra*(Constellations).[6] In ancient times, *Jyotish Shastra* primarily served to calculate time, to predict eclipses, to determine auspicious moments for rituals, ceremonies, and offerings. However, in modern times, *Jyotish* has also proven to be valuable in medical area for early detection of possible diseases and treatment purposes. *Jyotish Shashtra* believes that the situation of planets affects the individual's mental status and also affects the physical health.[7]It also helps to predict the possible future outcomes and events in person's life. *Jyotish Shastra* offers the solutions which can be used as preventive measures and curative measures for wellbeing.[8] *Ayurved* represents the ancient Indian tradition of medical science.[9]It is believed to be *Upaveda* derived from the *Atharvaveda*,[10]thus tracing its origins back to the *Vedic* tradition. *Ayurved* is a science of life. *Ayurved* teaches a way to live prosperous life without ailments. *Ayurved* provides the social and behavioural conduct.[11]*Ayurved* also teaches to have desirable life, enough wealth to live comfortable life and to wish for salvation(healthy life without diseases).[12]The goal of *Ayurved* is to prevent potential illnesses and alleviate the suffering of individuals through treatment.[13]*Ayurved* emphasizes the importance of preventing future health issues by promptly identifying symptoms through careful observation of symptoms. Ancient Indian scholars advised treating diseases promptly to prevent their further spread. Therefore, both *Jyotish* and *Ayurved* prioritize the holistic well-being of individuals, encompassing both mental and physical health, and even spiritual wellness. These two disciplines share intertwined similarities. Objectives of this article are to explore intertwined aspects and the interrelation between *Jyotish* and *Ayurved*.

MATERIALS AND METHOD

Jyotish is sixth *Vedanga*. [14] *Jyotish* is mentioned in *Rigveda*, *Yajurveda* and *Atharvaveda*. [15]Some people say *Ayurved* is the fifth *Veda*. [16]It is *Upaveda* of *Atharvaveda*. *Jyotish* and *Ayurved* share numerous similarities, aiming to alleviate mental, physical, and spiritual distress in individuals. The word 'Jyotish' is mentioned In *Charaka Samhita Chakrapani Teeka*, *Ashtanga Samgraha* and *Ahstanga Hridaya*. In *Upakalpiniya Adhyaya*, *Sutrasthana* of *Charaka Samhita Acharya Chakrapani* referenced *Jyotish* regarding the timing for medication intake. [17]He advised that individuals undergoing for *Vamana* and *Virechana* procedures should seek blessings from *Brahmanas* at the appropriate *Nakshatra*, *Tithi*, *Karana*, *Muhurta* and take medicine for procedure. For those undergoing *Shodhana Kriya*, it is recommended to take medicine during auspicious *Nakshatra* such as *Pushya*, *Hasta*, *Jyeshtha*, *Rohini*, *Shravana*, *Ashvini* etc. It is advised against taking medicines during other *Nakshatras*. [18]In *Dutadivignaniya Adhyaya*, *Shareera Sthana* of *AshtangaSamgraha*, *Vaidyas* are advised to consider 108 favourable indicators while leaving their residence and entering a patient's home. Among them one of the factors is *Jyotish*. [19] In *Dinacharya Adhyaya SutraSthana* of *Ashtanga Hridaya*, same has been told to note the factors while going to visit the patient's home and *Jyotish* is one of them. [20]

Observations

- In *SutraSthana* of *CharakaSamhita*, glimpse of *Jyotish* is seen. The pursuit of *Ayurvedic* knowledge arose from the necessity to alleviate illnesses. [21] According to *Charaka Samhita*, *Acharya Bharadwaja* sought the wisdom of *Ayurved* from Lord *Indra* during a time of widespread ailments among the people. Thus, the acquisition of *Ayurvedic* knowledge was driven for the welfare of society. [22] Similarly, in *Jyotish*, knowledge was pursued for the betterment of people's well-being. [23]
- In *Jyotish*, the study revolves around *Graha* (planets) – *Nakshatra* (Constellations) and their movements. [24]*Jyotish* identifies nine *Graha*(planets). For instance, *Surya* (Sun) transitions towards the *Uttara Disha* (North direction) during *Uttarayana*. [25] Auspicious ceremonies are preferred during *Uttarayana*, while *Dakshinayana* is avoided for sacred activities. Likewise, in *Ayurved*, *Samskaras* are recommended mainly to be conducted during *Uttarayana*. *Charakaacharya* mentioned that universal *Vayu* maintains the movement of *Surya*, *Chandra* and *Nakshatra*. [26]
- *Acharya Charaka* gave three types of treatment in *SutraSthana* of *CharakaSamhita*. 1. *Daivaavyapashraya Chikitsa* 2. *SatvavajayaChikitsa* 3. *YuktivyapashrayaChikitsa*. In *DaivaavyapashrayaChikitsa*(treatment), they included *Mantra*(Incantations), *Aushadhi*(Talisman), *Mani*(Gems), *MangalBali*(Auspicious offering), *Upahara*(Gifts),





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Homa(Oblations), Niyama(Observance of scriptural rules), Prayaschita(Atonement), Upavasa(Fasting), Japa(Prayer) etc. [27] In Jyotish, the solutions given are recitation of Hymns (MantraUccharan), Japa, Homa, Manidharana, Archana(prayers) of God.[28]

- In Vimana Sthana of Charaka Samhita, Acharya mentioned certain time and day for performing procedure. Jyotish has five Angas(parts) i.e. Tithi, Nakshatra, Vara, Karana and Yoga.[29] In Jyotish, Kala(time) is counted by these factors. In ancient time, Jyotish was used for obtaining information about Dina(day), Saptaha(week), Paksha(fortnight), Masa(month), Ayana (group of 3 seasons), Ritu(season), Samvatsara(year). An auspicious day or time is selected to perform certain sacred rituals and events with the help of Jyotish. Acharya Charaka mentioned specific Nakshatra, Tithi, Muhurta and Karana for Shishyopanayana Vidhi in Vimana Sthana.[30] Acharya Charaka mentioned in Vimana Sthana, that due to abnormality of Nakshatra, Graha (Planets), Chandra(moon), Surya(sun) etc Rutuvikara (seasonal abnormalities) are created means abnormal signs of seasons are seen.[31]
- Ayurved has a concept of Prakriti(constitution). Prakriti is decided at the time of birth. Prakriti indicates particular behaviour and habits of a person. Jyotish also indicates mental and physical status of a person based on the time of birth and day. It anticipates certain exploits depends on their birth charts. In Ayurved, Prakriti is explained by Acharyas. Sharirika and Manasika Prakriti are explained. Vata, Pitta and Kapha Prakriti and their combinations are SharirikaPrakriti.[32] In Jyotish, Graha(planets) also have their Prakriti(nature).Surya-PittaPrakriti, Chandra-VataKapha Prakriti, Mangala-Pitta Prakriti, Budha-KaphaVataPrakriti, Guru-KaphaPrakriti, Shukra-KaphaVataPrakriti, Shani-Vata Prakriti, RahuKetu-VataPrakriti.[33] Planets have their characteristics according to their nature just like persons have their behaviour and habits according to their Prakriti.
- Shareera Sthana of Charaka Samhita has mentioned specifically that Pushya Nakshatra should be selected for Pumshavanakarma.[34]Particular time is mentioned for entering of Sutikagara i.e. KalyanaKarana, Maitre Muhurta and sacred Nakshatra.[35] Namakarana Samskara is mentioned by Acharya Charaka in JatisutriyaAdhyaya. Acharya told to name the child by Its Nakshatrika Name (in which Nakshatra child is born, named accordingly).[36]Ayurved gave the Loka-Purusha Samya Siddhanta, which means whatever is in body, same exists in universe.[37]
- AcharyaSushruta explained that there are three Dosha in our body i.e. Vata, Pitta, Kapha. Similarly, the universe is run by Anila (Air), Surya (Sun) and Soma (Moon).[38] If these Dosha remain in normal state, then body works well but if they are imbalanced, they create disturbance in body. Similarly, in Jyotish if the Graha(planets) are in their Swagruha (own place), they appear normal but if they are in NichaSthana (Inferior state, not in normal position) they cause disturbance in individual's mental and physical state. Moon affects the mind of the person and behaviour.[39]
- Ayurved gave three mental faculty. i.e. Satva, Raja and Tama.[40] In Jyotish, Planets also have their Guna. Surya-Satvik, Chandra-Satvik, Mangala-Tamas, Budha-Rajas, Guru-Satvik, Shukra-Rajas, Shani-Tamas. [41]SatvaGuna is Superior in virtue. Raja is needed to run body and universe and Tamas is believed to be inferior in virtue.
- In IndriyaSthana of CharakaSamhita, Jyotish is mentioned. If a person sees destruction of Surya, Chandra and Nakshatra in his dream, it is said to be inauspicious.[42]
- In ChikitsaSthana, AcharyaCharaka mentioned the person to enter the Kutifor the KutipravesikaRasayana procedure in UttarayanaKala, ShuklaPaksha and ideal Tithi, Nakshatra, Muhurta and Karana.[43]Acharyas told to collect the medicine in best Muhurtaafter praying to God and well wishes from the Brahmanas.[44] AcharyaCharaka told to have Amalaki fruits in ShuklaPurnimaTithi of Posha orMagha or Falguna month after chanting of GayatriMantra for one year. PurnimaTithi is auspicious and believed best for work to be done.[45]
- In SiddhiSthana of CharakaSamhita, Acharya told to give AsthapanaBasti in auspicious day and Nakshatra. AcharyaHarita said to treat the disease in KrishnaPaksha because strength of disease is increased in that time. And its best time to eliminate the diseases.[46]AcharyaCharaka told to triturate the drug in PushyaNakshatra because it enhances the attributes of drug.
- In KashyapaSamhita, Acharya told to do MarutiIshti (Oblation) if there abnormal teeth in child.[47] There also AcharyaKashyapa said that pupil should not study during full moon, new moon and Ashtami.[48]
- AcharyaSushruta gave a concept of ShatakriyaKala (Six stages of disease manifestation). So, we can understand from the earlier stages how symptoms will be shown in future if left untreated.[49] In JyotishShashtra, from the positions of planets, future outcomes can be predicted.





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- In *AshtangaHridaya*, Acharya Vagbhata told to wake up early in *BrahmaMuhurta* daily.[50] Acharya Vagbhata mentioned *Daivavyapashraya Chikitsa* in *JvaraChikitsa* chapter, treatment mentioned in *Atharva Veda*. [51]
- Acharya Sushruta mentioned to bath a child influenced by *Skandagraha* disease with water chanted with *GayatriMantra*. [52] Offering should be done on *Shashthi Tithi* for the child who is suffering from *Naigameshagraha*. [53]

DISCUSSION

Both disciplines of *Ayurved* and *Jyotish* have aim to treat the issue regarding health and take necessary measures to prevent the possible future illness. *Ayurved* also told that to gain a proper and deep understanding of the concept, one must study other books too. Both *Jyotish* and *Ayurved* have similar concepts on *Prakriti*, *Sharirika* and *Manasika Dosha* and *Guna*, similarities between the body and the universe (*Loka-Purush Samya Siddhanta*). *Jyotish* provides solutions in form of prayers, *Mantra* recitations, wearing gems, offerings gifts to gods, *Homa*, fasting, riddance of anger-greed-jealousy, which are also called *Daivavyapashraya Chikitsa* in *Ayurved*, one of the *Chikitsa* mentioned by Acharya Charaka. In fact, Acharya Charaka mentioned *Daivavyapashraya Chikitsa* first. In *Varnasvariya Adhyaya* in *Charaka Samhita* *Indriya Sthana*, Chakrapani mentioned about *Samudrika Shahstra* that is *Jyotish*. [54] Acharya Sushruta told about organs and their *Devta* (God). From that we can understand that the effects of *Graha* occurs on mind and organs, and by taking preventive and curative steps, the health and psychological issues can be prevented. [55] Both sciences understand the importance of *Kala* (time). In *Jyotish*, the *Nakshatra*, *Graha*, *Tithi* moves at a particular time and they have their specific effects on person's body and mind. Solutions are also given to perform at specific time, too. Same way *Ayurved* also have the concept of *Shatakriya Kala*, which shows the significance of time. Time is precious in medical field for physician forearly diagnosis and early treatment in which if the physician does not diagnose the disease earlier by symptoms, then it will be difficult to treat it on later stages. [56]

Some medicines mentioned to give on early stages of diseases and some to be given after some time. Concept of *Ausadha Kala* is there i.e. medicines are given to different times according to the need of diseases. [57] In today's modern era, everyone asks for proof before believing in the concept. The scepticism faced by both *Jyotish* and *Ayurved* in today's time. There are challenges of integrating these ancient practices with today's contemporary medical science. There are so many potentials areas for further research and exploration in the integration of both *Ayurved* and *Jyotish* like in today's fast era, everyone wants the speedy result but these both science requires time and patience. The persons in dire need in search of relief come and agree to these sciences. There also research done in field of *Ayurved* to identify the possible causative factors of *Vandhyatva*. [58] The physician believed to be *Yuktigna* (intelligent enough to plan the treatment in less time with less medicines and solutions), using that he can plan a treatment combined of these both sciences to treat a disease for fast recovery. *Ayurved* has *Satvavajaya Chikitsa* which means having control on mind to not indulge in unnecessary and harmful factors or things. Peace of mind can be gained by following *Ashtanga Yoga* i.e. *Yama*, *Niyama*, *Asana* etc which is on spiritual level. *Jyotish* also believes in *Mantra* chanting and doing prayers to god which are spiritual. Considerations should be made to combine both spiritual or astrological guidance with medical advice.

CONCLUSION

Jyotish and *Ayurved* both believe in spirituality. *Ayurved* has *Daiva Vyapashraya Chikitsa* for the *Karmaja Vikara* and *Jyotish* also gives solutions similar to that. The integration of *Jyotish* and *Ayurved* offers a framework for enhancing health. Early diagnosis and early treatment can be achieved by combining both sciences. Through insights and practical, one can achieve a more balanced state of physical, mental wellbeing and spiritual level. Synergy between two ancient sciences underscores the holistic philosophy that true wellness arises from harmony between the cosmos and the individual. This shows how astrological principles can enhance *Ayurved* practices, offering a unique perspective.





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***Plectranthus barbatus* Andrews: Unveiling the Phytochemical Symphony and Advancing Molecular Barcoding for Reliable Identification in Herbal Products**

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ABSTRACT

Plectranthus barbatus Andrews contains several bioactive components, making it a chemically diversified plant that is a treasure trove for obtaining terpenes and other phytochemicals. The chief phytochemicals obtained from *P. barbatus* are labdane diterpenes, followed by phenolic compounds, Essential Oils (EOs), tannins, flavonoids, and saponins. Owing to its vast phytochemical diversity, *P. barbatus* is used for several herbal preparations. The major products are the forskolin containing weight loss capsules and powders of its roots. Therefore, the plant is widely used in several organic anti-obesity product preparations. A reliable identification marker is needed to combat intentional and accidental adulteration in the industries. The highly conserved quadripartite plastome is a promising tool for DNA barcoding, but the conventional markers such as *rbcL* and *matK* are not 100% accurate for all the lineages. This review aims to compile various phytochemicals isolated from this plant, to highlight the need to develop advanced plastome molecular markers for barcoding of *P. barbatus* Andrews, and to stimulate the use of a novel approach that is complemented with DNA barcoding, i.e. the use of non-invasive biophoton emission signature for its ability to check the adulteration in its herbal products.

Keywords: Anti-obesity, Barcoding, Biophoton, Phytochemistry, Plastome, *Plectranthus barbatus*





INTRODUCTION

Housing more than 7000 species, Lamiaceae is the largest of 26 families of Lamiales and the 6th biggest family of angiosperms in terms of species number [1]. *Plectranthus* L'Hér., also known as the genus of 'spurflower plants', is a multifaceted complex genus of Lamiaceae, which includes widely used horticultural and medicinal plants. *Plectranthus* belongs to Tribe Ocimeae, Subtribe Plectranthinae, and includes about 300 plant species distributed over East and Central Africa (>200 species), Arabian Peninsula, Indian Subcontinent to SC China (>22 species) and Australia (>40 species) [2]. It also grows in some parts of Brazil, Pakistan, and Sri Lanka [3]. One such pharmaceutically vital member of this genus is *Plectranthus barbatus* Andrews, which is commonly referred to as 'Dala Garmar' in Gujarati, 'Pattharchur' in Hindi, 'Maimnul' in Marathi, and also several botanical synonyms such as *Plectranthus forskohlii* Briq., *Coleus forskohlii* auct., *Coleus barbatus* (Andr.) Benth. [4]. Taxonomically, the "*Plectranthus*–*Coleus* complex" has long been a subject of debate among botanists. At present, the genera *Plectranthus* and *Coleus* are combined by Japanese botanists into the single genus *Plectranthus* [5], which is also supported by a molecular study carried out by Paton and colleagues in 2018 [6]. *Plectranthus barbatus* Andrews is a perennial herb, scattered across the tropical and sub-tropical zones of the Indian subcontinent and is cultivated commercially by local farmers of Gujarat for its roots ('Garmar' in Gujarati) which are traditionally used in preparation of pickles [7]. In Gujarat, it is cultivated mainly in the Saurashtra regions of Veraval, Khambhadiya, and Madhapar [7]. *P. barbatus* Andrews is a commonly used therapeutic plant species in India (both Ethno and Ayurvedic treatments), East and Central Africa, Federative Republic of Brazil, and the People's Republic of China. It is used to treat various ailments like dysentery [8], Nausea [9], liver fatigue, general respiratory ailments [10], cardiac disorders [11], ringworms and certain brain disorders like epileptic fits (Seizures which causes body to jerk and shake) [12]. The ancient Indian medicinal text book 'Ayurveda' describes the use of a plant named "Pashanabhedhi" and "Balakah" (Sanskrit names), as a remedy to treat various ailments like cardiovascular disorders, pulmonary, kidney, and certain neurological diseases. In the latter years, one of several plants linked to the above-mentioned plant was *Coleus amboinicus* Lour [3]. As a result, *Coleus amboinicus* Lour and its taxonomic relatives were included in the studies for the exploration of novel pharmacologically active compounds. Among such taxonomic relatives was *Coleus forskohlii* Briq., presently known as *Plectranthus barbatus* Andrews [3].

The root extract of *P. barbatus* Andrews in methanol exhibited hypotensive activity [3]. In the latter years, chromatography studies on silica gel of methanolic extract of this plant led to the discovery of numerous labdane diterpenes as major active phytochemicals including the main constituent Forskolin (formerly known as 'Coleonol') and a more recently characterized abietane diterpene i.e., Plectrabarbene [13]. Originally named 'coleonol', Forskolin was discovered by Forskal (1774), a Finnish botanist. Since then, as other diterpenoids and iso-coleonols have been isolated, the compound is now renamed as 'forskolin', after its discoverer Forskal [14]. The main pharmacological activities of *P. barbatus* Andrews are attributed to a single compound, the diterpene 'Forskolin'. It is the primary component of the roots, which is known to activate the enzyme class of Adenylate Cyclases (ACs), which converts ATP to cyclic AMP (cAMP), a secondary messenger in the G-Protein Coupled Receptor (GPCR) signaling pathway [10]. Forskolin-induced cAMP is known to stimulate lipolysis, which has been experimentally concluded in the case of Obese Men [15] and mildly overweight women [16]. However, some experimental evidence suggests that additional phytochemicals, such as volatile oils and other diterpenoids of the roots, may influence the absorption and activity of forskolin [17]. This review aims to highlight the phytochemical importance of this plant, especially the anti-obesity compound Forskolin, and to stimulate research for finding novel plastome barcodes for its authentic identification and industrial exploration.

PHYTOCHEMISTRY OF PLECTRANTHUS BARBATUS

Phytochemical studies have targeted to discover novel compounds with potential pharmaceutical applications. A total of 109 compounds found in various parts of *P. barbatus* Andrews, categorized into 7 groups and 6 major classes, are listed in Table 1 [3,5,13,19-55]. The primary components are the 69 Diterpenoids, 25 Phenolic compounds, 12 Major EOs, tannins, flavonoids, and saponins. The 69 diterpenoids have been sub-classified into 5 groups: Abietane diterpenoids (26); 8,13-Epoxy labd-14-en-11-one diterpenoids (27); 8,13-Epoxy labd-14-en-11-one diterpene





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glycosides(5);8,13-Epoxy-labd-diterpenoids with some deviations(6) and miscellaneous labdane diterpenoids(see Table 1). Terpenes aid in protecting the plant against biotic and abiotic stresses and attracting pollinators [18]. From **Table 1** we can infer that almost all the phytochemicals of *P. barbatus* Andrews growing in India are obtained from its roots. Whereas, in Brazil, most diterpenoids were isolated from the leaves and stems, and from the leaves East Africa (Kenya). Phytochemicals are abundant in leaves, roots, and whole plant extracts from China. In Italy, a total of 128 EOs have been identified through GC-MS analysis of different plant parts, out of which 12 EOs that make up 98.68% (quantitatively) of the total 128 EOs are listed in Table 1 [19]. The whole plant extract of *P. barbatus* in Italy is rich in essential oils with the highest proportion in roots, followed by leaves and stem [19]. Tannins, Saponins, and Flavonoids have been identified in the leaves from Nyamira County, Kenya (see Table 1) [20]. Therapeutic actions of medicinal plants are determined mainly by their secondary metabolites. The 22-carbon lipolytic plantditerpene forskolin stimulates all isoforms of mammalian adenylate cyclases (ACs) except the membrane-bound $G\alpha_s$ -activated enzyme AC9[56].As summarized in **Table 2**, several clinical trials (8-12 weeks long for humans and 16 weeks long for mice) have been conducted in the past to check the efficacy of *P. barbatus* root extracts in reducing weight [15, 16, 57-61]. None of the studies reported any major side effects, but several participants reported mild diarrhoea which was not considered as clinically significant [57]. The Crypts of Lieberkühn cells near the base of intestinal villi, secrete ions (Na^+ , K^+ and Cl^-) in the intestine, through their series of transporter channels.

It is an intrinsic mechanism of our body to generate an osmotic potential gradient across the epithelium that leads to the endosmosis of H_2O into the small intestine; and in turn, maintain its physiological functioning [57]. Cystic Fibrosis Trans membrane Conductance Regulator (CFTR) channel of ABC (ATP-binding cassette) super family of transporters is located at the luminal face of the crypt epithelium and consists of 5 domains out of which 2 are trans membrane protein domains that functions as a cAMP-dependent Cl^- channel [62, 63].This channel is commonly found at 2 major sites, epithelial membrane lining the lumen of digestive system, and the respiratory system i.e. Tracheo-bronchial tree. When the plantis consumed, forskolin increases intra-cellular concentrations of cAMP within the crypt cells and activates the CFTR channel that transports Cl^- anions across the epithelium, into the digestive lumen. The formation of $NaCl$ salt in the small intestine, created as a collective result of the charge-concentration gradient generated by the accumulation of Cl^- anions in the crypt and its stimulation of the passive diffusion of positively charged Na^+ ions into the lumen, presumably across the Occluding junctions/Tight Junctions[57].When $NaCl$ is secreted into the crypt, the lumen experiences a negative osmotic gradient, which results in endosmosis of H_2O into the digestive lumen. Theoretically, this could result in soft stool and diarrhea observed during the clinical trials[57]. Most of the clinical trials are of very short duration (56 to 84 days long). Further trials are needed to find out the long-term effects of forskolin consumption in humans and to establish the root as a safe and effective weight loss and other personalized supplements and medicines. For compounds other than Forskolin, no clinical trials could be identified for the plant.

Hydrolysable Tannins (HTs), with a carbohydrate core, are plant polyphenols commonly found in a wide range of plants, including the leaves of *P. barbatus*. They are composed of a central core of carbohydrates (typically Dextrorotatory(D)-glucose) that is esterified with phenols, like Gallic acid (GA) and Ellagic acid (EA). HTs have been shown to have antioxidant activities on copper and iron-mediated formation of free-radicals [64, 65], as well as inhibitory effects on gastric Proton- K^+ -ATPase pump[66]. This suggests that the leaf extract of *P. barbatus* can be used for potential Treatment of Diarrhoea. However, their effects on CFTR Cl^- channels of the digestive tract have remained unknown so far [67].So, the Forskolin of the root and HTs of the leaf of *P. barbatus* are antagonistic in their function. Thus, a combination of root and leaf extract of *P. barbatus* Andrews can be administered to mitigate the mild diarrhea experienced during the clinical trials of forskolin, while maintaining its lipolytic efficacy. Recent studies show that roots are also abundant in phenolic compounds, the chief constituent being flavonoids. Rosmarinic acid was the dominant phenolic compound in almost all ethanolic root extracts but it is not so in water extract [54]. Rosmarinic acid incorporated intonutritional dietary supplements or other drugs can be used to treat digestive ailments. Water extracts of *P. barbatus* root were found to exhibit the lowest antioxidant capacity as compared to 40%, 60%, and 80% ethanolic extracts[54]. Kulbat-Warycha and colleagues (2022) reported that the 80% ethanol solution was the most efficient solvent for flavonoid extraction, whereas 40% and 60% ethanolic extracts are most suitable for





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the isolation of the total polyphenol pool from its roots [54]. Phenols from the plant roots such as EA and GA, can inhibit seed germination, plant development, and fungal growth [68, 55]. Thus, phenolic compounds may serve as a defence mechanism for the plant against soil fungal parasites and other growth competitors. A fascinating question arises from the above observations that is why does *P. barbatus* produce forskolin? One theory suggests that the purpose is protection against soil pathogens as it is highly susceptible to root rot/wilt infection by numerous strains of pathogenic fungi, the major one being *Fusarium chlamydosporum* [69]. The fact that a large number of pathogens use the same basic strategy for infection by escalating cAMP levels in host cells to manipulate the cell environment, increase virulence gene expression, and manipulate host immunity [70] suggests that cAMP manipulation is crucial for pathogenicity. Forskolin is believed to be the tit-for-tat counterattack against the pathogens by the plant. This statement is based on the fact that forskolin is produced and stored only in the specialized oil bodies present in the periphery of the root i.e., the cork cells [71]; its nature to activate ACs; as well as some AC independent functions like inhibition of GLUT (Glucose transporters), competitive inhibitory of effects of the myco-metabolite 'Cytochalasin B' [72]. The oil bodies in the cork cells are the first cells that come in contact with any pathogen/mycelium. The oil containing forskolin might be working like a 'trojan horse' that when absorbed by the pathogen for nutrition, wreaks havoc at the cAMP levels and its related responses of the pathogen from within its own cells. This suggests that *P. barbatus* produces forskolin as a line of defence against root pathogens. However, every rose has its thorns, forskolin is not effective against all pathogens. Fungal pathogens like *Ustilago maydis* without cAMP and its effect or enzyme Protein Kinase A (PKA) show constitutive filamentous growth, which is reversed by exogenous cAMP exposure or gain-of-function mutation in the regulatory subunit of PKA [73].

On the contrary, in *Magnaporthe grisea*, intracellular cAMP levels regulate the recognition of the plant surface and stimulate pathogenic developments. Moreover, the addition of cAMP analogs like 8-bromo cAMP and N6-monobutyryl cAMP to vegetative hyphae and conidia possibly retarded vegetative growth and as a result, induced appressorium formation [74]. Increased cAMP can be helpful against *U. maydis* but could produce higher infection of *M. grisea*. The reason why *P. barbatus* suffers significant root damage by *Fusarium chlamydosporum* is possibly because increased cAMP levels due to forskolin might aid in its pathogeny-related developments. Extensive research is required to determine the effects of forskolin on different pathogens, thus opening the possibility of using Forskolin as an anti-fungal, anti-microbial agent against all plant and human pathogens that cannot survive/develop in high cAMP environments. *Plectranthus barbatus* Andrews is widely used in the industries for the preparation of several herbal products. The major herbal products are the forskolin-rich weight-loss capsules and powder prepared from its roots. On account of its diverse medicinal applications, and to ensure the best quality of its supply, especially in the times of rampant adulteration and substitution in the markets of India, there is a dire need for personalized identification strategies for *P. barbatus*. Srivastava *et al.* (2002) reported that the Forskolin content of *P. barbatus* from south India (Andhra Pradesh) is higher than that of North India (Uttar Pradesh) [75]. On the other hand, protein content was higher in Uttar Pradesh counterparts compared to South India. Tannin content didn't show much variation in both regions, however, starch content correlated with forskolin concentration in the root powder [75]. It is evident from the above report that the biochemical profile is highly dynamic, it changes with the geographical region in which the plant develops and can give misleading results during specimen identification. Therefore, the situation presses for the development of efficient plastome DNA markers for this plant. Linking biochemical and plastome variation data in *P. barbatus* from different geographical regions can help in screening the plants with higher forskolin content while simultaneously exposing adulteration.

AUTHENTICATION AND BARCODING OF *PLECTRANTHUS BARBATUS*

Despite almost 270 years of taxonomic efforts since Carolus Linnaeus coined the term "Taxonomy", the characterization and precise cognition of plant species remains a substantial challenge to this day. The endosymbiotic genesis of chloroplast and mitochondria is now universally accepted, owing to genomic similarity evidence that is stronger than ever. Studies by Falcón *et al.* (2010) linked 16S rRNA and *rbcL* genes (ribulose 1,5-bisphosphate carboxylase/oxygenase) which suggests that chloroplast resulted from endosymbiosis of a nitrogen-fixing unicellular cyanobacteria [76]. Four decades ago, we viewed the evolution of mitochondria and chloroplast like two sides of the same coin. However, recent pieces of evidence argue that the host cell that incorporated the α-





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proteobacteria was prokaryotic and not a eukaryotic cell[77]. This raises the possibility that endosymbiosis might've been crucial for eukaryogenesis. This points towards the highly malleable nature of organelle genomics. Even though the origin of chloroplast is still a point of debate, the credibility of plastome for specimen identification and phylogenetic analysis is well established among evolutionary biologists. Thus, the plastome is widely used in DNA barcoding and phylogenetic studies of plants. Adulteration can be unintentional due to a lack of skilled taxonomists for accurate identification, phenotypic plasticity due to changing environmental conditions, or intentional adulteration to maximize profits. Since *Plectranthus barbatus* Andrews is an economically important plant, owing to its huge arsenal of secondary metabolites as shown in Table 1, plastome comparative studies along with barcoding will prove to be very useful for its precise recognition and exposing adulteration in its commercially available products. "DNA barcoding" is a 21-year-old term coined by Prof. Paul David Neil Hebert, a Canadian biologist in 2003. It is defined as a technique for recognizing organisms by using single/multiple DNA sequence(s) from specific regions of nuclear genome, chloroplast genome (plastome) or mitochondrial genome (MG) termed "DNA barcodes", to make taxonomic studies swifter and more accurate, enhance adulteration analyses, and to get better resolved phylogenetic trees. While for most fauna, the accepted barcode sequence is the Cytochrome Oxidase complex (complex IV of ETC) gene of the MG, it is a ubiquitous and relatively precise system for animal DNA barcoding. Since the efficiency of individual DNA barcodes varies widely throughout taxa, there are very few comprehensive single DNA barcodes for plants to this day. The British botanist Peter M. Hollingsworth and colleagues from "Plant Working Group" of Consortium for the Barcode of Life (CBOL) initiative compared performance of 7 genes of plastome from 550 species and proposed a combination of portions of two coding regions from the plastome as core barcodes for plants—*rbcL* + *matK*[78], to be augmented with additional family/genus specific genes like *ndhF*, *rpl16*, *psbA*, *clpP*, as well as other regions of DNA such as Inverted Repeat (IR) region as required. The International community of CBOL accepted their recommendation, but with an additional clause that development of new barcode markers should be carried out to expand the existing knowledge of plastome barcoding[79].

As summarized in Table 3, it is clear that the traditional barcode genes are not equally competent across the plant kingdom and concatenated protein-coding gene sequences from plastomes show higher resolution than unaided single-locus barcode genes. It is evident that combination of multiple barcodes provides a better discriminatory power, but in some cases the efficiency of multiple-locus barcode is lower than single locus genes as shown by de Vere [84]. Therefore, instead of single or multiple genes, several researchers supported the use of the whole plastome as a 'Super Barcode'[86-91]. Single-locus barcodes lack adequate variations while the whole plastome super-barcode currently can be resource intensive. Some other issues with super barcodes that need to be solved, i.e., intraspecific sampling remains inconsistent, and discrimination is not rapid and may be too complicated for laboratories that lack the necessary knowledge and experience. There must be a 'golden mean' which can concurrently solve the limitations of both traditional barcoding and super-barcoding. To work out this current challenge, the authors support the concept of using specific 'Pro-barcode' which involve the use of all the protein-coding genes together (Concatenated protein-coding sequences) as a barcode, since any organism is ultimately the resultant of its expressed proteins. Pro-barcode refers to an intermediate of single-locus and super-barcode. Pro-barcode is of apposite length so as not to compromise between variability, efficacy, and plausibility. Pro-barcode can be used to improve the resolution of phylogenetic trees, including the *Plectranthus barbatus* Andrews housing family Lamiaceae. Rapid evolutionary radiations could account for the higher degree of diversity in different lineages as they are ubiquitous across all forms of life. Besides barcoding, plastomes can also be used to gain more insights into the evolution, speciation, and adaptation of a lineage using recent radiations as models. A phylogenetic tree for different plant lineages that is accurate and well-resolved is needed to understand the complete history of plants. However, determining phylogenetic relationships by considering recent radiations has been difficult because no traditional phylogenetic DNA markers are able to provide enough information and clarity for all lineages. Because of low mutation rates, high copy number, and uniparental inheritance, plastome DNA could significantly improve the resolution of phylogenetic trees in plant groups resulting from recent radiations as shown in 23 species of the *Rhodiola* genus, a recent rapidly diverging group of Crassulaceae family on the Qinghai-Tibetan Plateau [92]. Since no individual barcode can resolve all lineages, Pro – barcodes could be the answer to further refine the phylogenetic trees and possibly differentiate between recently diverged closely related species as reported by Jiang *et al* for 3





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cultivated varieties of *Scutellaria baicalensis* Georgi [93] and also by Bhatt and Thaker for 82 species of Poaceae Grasses from Kutch desert, Gujarat [80]. The plastome of *P. barbatus* from Portugal is 157,467 bp long and has 133 genes, including 87 CDS sequences [94]. Since *P. barbatus* Andrews can be easily adulterated by *P. neochilus* Schltr and *P. grandis* (Cramer) R. Willemse [95] because of similarity in leaf morphology, it is necessary to develop barcodes for accurate authentication of the former plant. Several phylogenetic and barcoding analyses of *P. barbatus* plastome have been performed using whole chloroplast genome [96-97], *rbcL* and *matK* [98], *rps16*, *trnL-F* and *trnS-G* [6]. However, no comparative barcoding studies of Indian *P. barbatus* with other Lamiaceae plants using the Pro-barcode have been reported so far.

A STEP BEYOND BARCODING

A different aspect that also needs to be addressed is the adulteration in herbal products beyond the species/variety level. Ayurveda, a text on conventional Hindu medicine, states that for a plant's optimal therapeutic efficiency, specific plant tissues should be harvested at particular times of the year [99]. If the tissue of the same plant is harvested at the wrong time of the year (generally earlier than usual to maximize profits), its potency will not be up to the mark, and DNA barcoding will fail to catch this type of adulteration, responsible for compromising the quality standard of the herbal product. Therefore, DNA barcoding needs to be complemented with other tools and techniques so that it can be more accurately adopted for quality control purposes of Ayurvedic and other herbal products on the market [100]. Such a technique should be able to identify the metabolomic profile of the sample in real-time and preferably in a non-invasive manner. One such technique is to study the Biophoton or Ultra-weak Photon Emission.

BIOPHOTON: POTENTIAL DARK HORSE OF SPECIMEN IDENTIFICATION

Plastome barcoding for effective identification of adulteration in industries is just one-half of a two-part problem. The other half of the problem is the effective selection of plant parts in a specific physiological phase for maximum yield of desired phytochemicals, as the phytochemical profile of any plant is time-dependent and highly dynamic with different developmental stages of the plant, and the time of the year when the plant is studied. This part of the problem cannot be solved with barcoding and phytochemical testing of every batch can be uneconomical. Therefore, for the selection of perfectly suitable plant material, there should be a relatively simple, rapid, and cost-effective technique to predict the potency of plant material. One option is to perform the Biophoton emission analysis of the sample. Many metabolically active biological systems e.g., algae, fungi, plants, animals, and several microorganisms, show ultra-weak photons emission in the visible wavelength spectrum (380 to 700 nm), even after being devoid of light for many hours [101] and these emitted photons are termed as 'Biophotons' (Bio- γ). The Bio- γ radiating due to intrinsic metabolism of an organism are termed as 'Spontaneous emission'. Besides this, a different type of luminescence is observed when the sample is subjected to an external light source, termed 'Delayed Luminescence' (DL). It is different from bioluminescence as the source of these Bio- γ is believed to be various enzymatic activities of the cells, respiratory chain in mitochondria, or the generation of various Reactive Oxygen Species (ROS) during metabolic activities of the cells [102]. DL is measured between the 2 – 200 second gap after the sample has been subjected to external light (background illumination). These Bio- γ are detected using PIAS Hamamatsu (Photo Image Acquisition System, Hamamatsu, Japan). DL is generally represented as a time-dependent 'Ln(Counts/Sec)' graph of negative slope. The delayed Bio- γ emission count differs for every species and it is also dynamic with the physiological phases (age) of plants belonging to the same species [101]. The Bio- γ emission count patterns for different parts of *Plectranthus barbatus* Andrews have not yet been standardized. The Bio- γ emission signature of *P. barbatus* Andrews can be used to non-invasively predict the physiological maturity stage of the plant material for cost-effective screening of the material that is rich in phytochemicals of interest, which will ultimately result in more potent herbal products.





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CONCLUSIONS

Plectranthus barbatus Andrews is a phytochemical-rich plant that is widely used in the industry for the preparation of various weight loss products, owing to the diterpene forskolin present in its roots. Other terpenes, phenolic compounds, tannins, and EOs make this plant industrially very important and prone to adulteration. In this review, we highlight the need of comparative analysis and plastome DNA barcoding study to provide a reliable way for quality control and removal of other morphologically similar plants, which will ultimately help to control all types of adulteration. Besides quality control, the Bio- γ DL signature analysis can also aid in rapid and hassle-free identification of the physiological maturity stage of the desired plant material. In the future, we hope to see a synchronized unification of Plastome DNA barcoding and Bio- γ analysis, which will help in the production of more potent herbal products with a higher amount of the desired phytochemicals from *P. barbatus* Andrews and several other Lamiaceae plants.

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Table 1. Various Phytochemicals found in *P barbatus* Andrews. *WP – Whole Plant

Sr. No.	Plant Part	Name of Compound	Geographical Location of <i>P. barbatus</i>	References
Chemical Class 1: Abietane diterpenoids				
1	Leaf	(+)-Allylroyleanone (Plectranthone J)	East Africa – Kenya	[21]
2	Leaf	Coleon S	China	[22,5]
3	Leaf	Coleon O	East Africa - Kenya	[23]
4	Leaf	Coleon T	China	[22,5]
5	Leaf	Plectrin	East Africa - Kenya	[21, 23]
6	Leaf	Barbatusin	Brazil	[24, 25]
7	Leaf	3 β -Hydroxy-3-deoxybarbatusin	Brazil	[24]
8	Leaf	Cyclobutatusin	Brazil	[24, 26]
9	Leaf	7 β -Acetyl-12-deacetoxycyclobutatusin	Brazil	[25]





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10	Leaf	(16R)-Coleon E	East Africa - Kenya	[21, 25]
11	Leaf	Coleon F	East Africa - Kenya	[21]
12	Leaf	(16R)-Plectrinon A	Brazil, East Africa - Kenya	[21]
13	Leaf	Plectrinon B	East Africa - Kenya	[21]
14	Root	14-Deoxycoleon U	China	[28]
15	WP	Coleon C	China	[29, 5]
16	Stem	6,7-Secoabietane diterpene I	Brazil	[30]
17	Stem	6,7-Secoabietane diterpene II	Brazil	[30]
18	Stem	Cariocal	Brazil	[31]
19	Root	Abietatriene (dehydroabietane)	India	[32]
20	Root	Demethylcryptojaponol (11-hydroxysugiol)	China	[28]
21	Stem	Ferruginol	Brazil	[33]
22	WP	Sugiol	China	[5]
23	Stem	20-Deoxocarnosol	Brazil	[34]
24	Stem	6 β -Hydroxycarnosol	Brazil	[35]
25	Stem	Barbatusol	Brazil	[33]
26	Stem, Leaf	Plectrabarbene	Saudi Arabia	[13]
Chemical Class 2: 8,13-Epoxyabd-14-en-11-one-diterpenoids				
27	Root	Forskolin	India, China	[3]
28	Root	9-Deoxyforskolin	India	[3]
29	Root	1,9-Dideoxyforskolin	India	[3]
30	Root	1,9 Dideoxy-7-deacetylforskolin	India	[3]
31	Root	Deacetyl-1-deoxyforskolin	India	[36]
32	WP	6-Acetyl-1-deoxyforskolin	China	[37]
33	WP	6-Acetyl-1,9-dideoxyforskolin	China	[37]
34	Root, WP	Forskolin A	China	[38]
35	Root, WP	Forskolin B	China	[38]
36	WP	Forskolin C	India, China	[38, 39, 48]
37	Root	1,9-Dideoxycoleonol B	India	[40]
38	Root, WP	Forskolin D	India, China	[38]

Table 1. cont.

39	Root, WP	Forskolin E	China	[38]
40	Root, WP	Forskolin F	India, China	[38]
41	Root, WP	Forskolin G	China	[41, 42]
42	Root, WP	Forskolin H	China	[42]
43	Root, WP	Forskolin I	China	[42, 43]
44	Root	Forskolin J	China	[43]
45	Root, WP	Forskolin K	China	[5]





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46	Root	Forskolin L	India, China	[36]
47	Root	Coleosol	India	[44, 45]
48	Root	1-Acetoxy coleosol	India	[40]
49	Root	Coleol	India	[46, 5]
50	Root	11-Oxomanoyloxide (8,13-epoxy-labd-14-en-11-one)	India	[5]
51	Root	Coleonol E	India	[47, 5]
52	Root	Coleonol F	India	[47, 5]
53	Root	Deoxycoleonol	India	[39, 48, 5]
Chemical Class 3: 8,13-Epoxy-labd-diterpenoids with some deviations				
54	WP	3-Hydroxyforskolin	China	[49, 5]
55	WP	3-Hydroxyisoforskolin	China	[49, 5]
56	Root	13-Epi-9-deoxycoleonol	India	[50]
57	Root	Coleonol C	India	[39, 48, 5]
58	Root	Coleonone (8,13-epoxy-labd-14-en-12-one)	India	[46, 5]
59	Root	Manoyl oxide (8,13-epoxy-labd-14-ene)	India	[5]
Chemical Class 4: 8,13-Epoxy-labd-14-en-11-one-diterpene glycosides				
60	WP	Forskoditerpenoside A	China	[51]
61	WP	Forskoditerpenoside B	China	[51]
62	WP	Forskoditerpenoside C	China	[52]
63	WP	Forskoditerpenoside D	China	[52]
64	WP	Forskoditerpenoside E	China	[52]
Miscellaneous labdane diterpenoids				
65	Root	13-Epi-sclareol	India	[53]
66	WP	Forskoditerpene A	China	[52]
67	WP	12-Hydroxy-8,13E-labdadien-15-oic acid	China	[37]
68	WP	Coleolic acid (11-ol,13-Me,8(9),13(14)Z-labdadien-15-oic acid)	China	[5]
69	WP	Coleonic acid (11-one,13-Me,8(9),13(14)Z-labdadien-15-oic acid)	China	[5]
Chemical Class 5: Phenolic Compounds				
70	Root	Quinic Acid	Poland	[54]
71	Root	Protocatechuic Acid	Poland	
72	Root	4-Hydroxybenzoic acid	Poland	
73	Root	Protocatechuic aldehyde	Poland	

Table 1. cont.

74	Root	Gentisic acid	Poland	[54]
75	Root	4-Hydroxybenzoic acid O-hexoside	Poland	
76	Root	Vanillic acid	Poland	
77	Root	Hydroxygallic acid	Poland	
78	Root	Syringic acid	Poland	
79	Root	p-Coumaric acid	Poland	
80	Root	Ferulic acid	Poland	
81	Root	2-Hydroxybenzoic acid	Poland	
82	Root	Ellagic acid	Poland	
83	Root	Caffeic Acid	Poland	
84	Root	Rosmarinic acid	Poland	
85	Leaf	Gallic Acid	Brazil	[55]





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86	Leaf	Boldine	Brazil	
87	Leaf	Rutin	Brazil	
88	Leaf	Quercitrin	Brazil	
89	Leaf	Quercetin	Brazil	
90	Leaf	Isoquercitrin	Brazil	
91	Leaf	Kaempferol	Brazil	
92	Leaf	Luteolin	Brazil	
93	Leaf	Ellagic acid	Brazil	
94	Leaf	Caffeic Acid	Brazil	
	Chemical Class 6: Major Essential Oils (EOs)			
95	WP	β -caryophyllene	Italy	[19]
96	Root	β - phellandrene		
97	Root	β -gurjunene		
98	Root	Humulene		
99	Stem	β -linalool		
100	Stem	α -copaene		
101	Stem	β -caryophyllene		
102	Stem	δ -cadinene		
103	Leaf	Anethol		
104	Leaf	β -caryophyllene		
105	Leaf	D germacrene		
106	Leaf	1-octen-3-ol		
	Other Phytochemicals			
107	Leaf	Tannins and Hydrolysable Tannins (HTs)	Kenya	[20]
108	Leaf	Flavonoids		
109	Leaf	Saponins		

Table 2. Humans and Mice Clinical trials to establish the lipolytic potential of forskolin from *P. barbatus* root

Sr No.	Dose of Forskolin	Test Subjects	Study Period	Results	Side Effects	References
1	25 mg	1 Male, 13 Females	12 weeks	Significant decline in body weight, body fat %, BMI	No major side effects	[58]
2	50 mg	Overweight women (6)	8 weeks	Significant decline in body weight and fat %	No major side effects	[59]
3	50 mg	Overweight women (30)	12 weeks	No weight loss but Prevented weight gain	No major side effects	[16]
4	50 mg	Overweight men (30)	12 weeks	Significant decline in body fat % and fat mass	No major side effects	[15]
5	100 mg	Normal Healthy volunteers (15)	8 weeks	Decline in BMI, fat %, and body weight as compared to week 0	No major side effects	[60]
6	50 mg	60 (Men + women)	12 weeks	Significant decline in body weight	No major side effects	[57]
7	0 mg (control), 2 mg/kg and 4 mg/kg	3 groups, 8-11 male mice per group	16 weeks	Mild Reduction in fat cell diameter and improved glucose metabolism	No major side effects	[61]



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Table 3. Level of Species Discrimination from various barcoding studies

Sr. No.	Habitat	Location	No. of Species	Markers used	% Species discrimination	References
1	Desert Grasses (Poaceae)	Kutch desert, Gujarat, India	193	atpF – atpH	43	[80]
				psbK-psbI	69.94	
				rbcL	91.19	
				rpoC1	86.52	
				rpoB	82.9	
				matK	96.37	
			82	Concatenated protein-coding genes	≥ 99	
2	Tropical Forest Trees	North-east Puerto Rico	143	matK	70	[81]
				rbcL	85	
				trnH – psbA	83	
				matK + rbcL	89	
				trnH-psbA + rbcL	93	
				matK + rbcL + trnH - psbA	93	
3	Tropical Forest Trees	Cameroon, Central Africa	272	rbcL	72.6	[82]
				matK	74.9	
				matK + rbcL	83.1	
4	Temperate Flora	Jokers Hill, Ontario, Canada	436	matK	88.3	[83]
				atpF – atpH	87.9	
				trnH – psbA	81.3	
				rbcL	79.7	
				rpoC1	72.7	
				rbcL+matK	93.1	
				rbcL+matK+trnH-psbA	95.3	
				rbcL+matK+trnH – psbA + rpoC1 + atpF – atpH	97.3	
5	Native Angiosperms and conifers	Wales, UK	1041	rbcL	97.7	[84]
				matK	90.2	
				matK + rbcL	89.7	
6	Regional Flora	Canadian Arctic and Alaska, U.S.A.	490	rbcL	42.6–42.9	[85]
				matK	55	
				matK + rbcL	56.3	





Innovative Sublingual Antihypertensive Tablets: A Quality by Design Approach

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ABSTRACT

Hypertension remains a leading cause of cardiovascular diseases worldwide, with effective management being crucial to reduce morbidity and mortality. Traditional oral antihypertensive medications often have delayed onset of action, making them less effective in urgent situations such as hypertensive crises. Sublingual drug delivery systems present a promising alternative by enabling rapid absorption, leading to quicker therapeutic effects. The application of Quality by Design (QbD) principles in the development of sublingual antihypertensive tablets is key to ensuring high-quality, consistent products. QbD emphasizes the identification and control of Critical Quality Attributes (CQAs) such as disintegration time, dissolution rate, and bioavailability. It also involves the careful selection of Critical Material Attributes (CMAs) and Critical Process Parameters (CPPs) that directly influence these properties. By utilizing tools like Design of Experiments (DoE), QbD facilitates the optimization of formulation and manufacturing processes to achieve robust drug products. Advanced technologies such as Process Analytical Technology (PAT) and continuous manufacturing techniques offer further opportunities to improve quality control throughout production. Integrating QbD principles into the development of sublingual antihypertensive tablets holds significant potential for improving hypertension management. This approach ensures rapid drug onset, enhanced bioavailability, and improved patient compliance. By addressing both clinical needs and regulatory expectations, QbD-based sublingual formulations can lead to better therapeutic outcomes and greater patient satisfaction, offering a promising solution for the future of hypertension care.





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Keywords: Hypertension, Sublingual Drug Delivery, Quality by Design (QbD), Antihypertensive Tablets, Critical Quality Attributes (CQAs), Design of Experiments (DoE)

INTRODUCTION

Hypertension, often referred to as the "silent killer," is a leading cause of cardiovascular morbidity and mortality worldwide. Affecting over 1.4 billion adults globally, it significantly increases the risk of heart attacks, strokes, kidney failure, and other severe complications. Despite advances in medical therapies, the control rates for hypertension remain suboptimal, with less than half of those diagnosed achieving target blood pressure levels. This alarming scenario highlights the pressing need for innovative therapeutic strategies to manage this condition effectively [1-3]. Hypertensive crises, characterized by sudden and severe elevations in blood pressure, can lead to life-threatening complications if not managed promptly. In such scenarios, rapid drug action is critical to preventing end-organ damage. Conventional oral medications may not provide the required immediacy due to delays in absorption and onset of action. This underscores the necessity for advanced drug delivery systems that can deliver therapeutic effects swiftly and effectively during emergencies [4]. Sublingual drug delivery offers a promising alternative for the management of hypertensive crises [5]. By bypassing the gastrointestinal tract and first-pass metabolism, sublingual tablets enable rapid absorption directly into the systemic circulation, ensuring a faster onset of action. Moreover, their ease of administration enhances patient compliance, especially among populations with swallowing difficulties or in emergency settings. Sublingual formulations provide a dual advantage: improved therapeutic outcomes and better patient adherence [6-11]. Incorporating Quality by Design (QbD) principles in pharmaceutical development has revolutionized the industry by ensuring product quality and performance through systematic and science-based approaches. QbD emphasizes the identification of critical quality attributes (CQAs) and critical process parameters (CPPs) to optimize formulations and manufacturing processes. Applying QbD to sublingual antihypertensive tablets can facilitate the development of robust, high-quality products that meet the therapeutic demands of hypertensive emergencies, thereby bridging the gap between innovation and regulatory compliance [12].

Hypertension and Current Treatment Strategies

Pathophysiology of Hypertension

Hypertension, or high blood pressure, arises from a complex interplay of genetic, environmental, and lifestyle factors. It is characterized by sustained elevation of arterial blood pressure due to increased systemic vascular resistance and/or cardiac output. Key mechanisms contributing to hypertension include [13-17]

- Renin-Angiotensin-Aldosterone System (RAAS) Dysregulation: Overactivation of RAAS leads to vasoconstriction, sodium retention, and increased blood volume.
- Sympathetic Nervous System (SNS) Overactivity: Heightened SNS activity promotes vasoconstriction and cardiac output, further elevating blood pressure.
- Endothelial Dysfunction: Impaired production of vasodilators like nitric oxide (NO) and increased release of vasoconstrictors exacerbate vascular resistance.
- Structural Changes in Blood Vessels: Chronic hypertension leads to vascular remodeling, reducing elasticity and perpetuating high blood pressure

Challenges in Existing Drug Delivery Methods

Current antihypertensive therapies face several limitations in their delivery [18-22]

1. **Delayed Onset of Action:** Oral drugs undergo first-pass metabolism, reducing bioavailability and delaying therapeutic effects.
2. **Poor Patient Compliance:** Complex dosing schedules and side effects contribute to non-adherence, undermining treatment efficacy.
3. **Limited Effectiveness in Hypertensive Crises:** Conventional formulations lack the rapid action required for emergency situations.





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4. **Stability Issues:** Some antihypertensive agents are sensitive to environmental factors, affecting their efficacy.
5. **Inconsistent Absorption:** Variability in gastrointestinal conditions and food interactions impact drug absorption.

Sublingual Drug Delivery System

The sublingual drug delivery system utilizes the highly vascularized mucosa beneath the tongue for direct absorption of drugs into the systemic circulation. This mechanism bypasses the gastrointestinal tract and first-pass metabolism in the liver, resulting in a faster onset of action compared to conventional oral formulations [23-25]. The thin mucosal barrier and extensive capillary networks under the tongue facilitate efficient drug diffusion into the bloodstream. Sublingual delivery offers several advantages, including rapid therapeutic effects, improved bioavailability, ease of administration without the need for water, and enhanced patient compliance. These attributes make sublingual delivery particularly suitable for managing acute conditions such as hypertensive crises [26]. Developing effective sublingual formulations requires attention to key factors such as drug permeability, solubility, and stability. Drugs intended for sublingual absorption must possess adequate lipophilicity and molecular size to diffuse through the mucosal membrane efficiently. High solubility is critical to ensure rapid dissolution in saliva, while pH compatibility with physiological saliva (6.0–7.0) enhances drug stability and reduces the risk of irritation. Additionally, rapid disintegration of sublingual tablets, ideally within seconds to minutes, is vital for prompt drug action. Stability under environmental conditions, such as humidity and temperature, and palatability through taste masking, are also crucial considerations for patient acceptance and product efficacy [27-33]. Sublingual tablets are increasingly recognized as a promising option for antihypertensive therapy, particularly in emergencies. Drugs such as nifedipine and captopril have been formulated into sublingual tablets to provide rapid relief during hypertensive crises. For instance, nifedipine's calcium channel-blocking properties and captopril's RAAS-inhibiting effects make them effective choices for sublingual delivery. Additionally, nitroglycerin sublingual tablets, although primarily used for angina, exemplify the potential of sublingual formulations for cardiovascular drugs. By ensuring swift absorption and immediate action, sublingual tablets address critical gaps in current antihypertensive treatments, offering a practical and efficient approach for acute blood pressure management. Further advancements, guided by Quality by Design (QbD) principles, promise to optimize these formulations, ensuring enhanced therapeutic outcomes and better patient care [34-36].

Quality by Design (QbD) in Pharmaceutical Development

Quality by Design (QbD) is a systematic, science-driven approach that emphasizes product and process understanding to ensure pharmaceutical quality. QbD principles involve identifying the critical quality attributes (CQAs) of a drug product and establishing a design space through a thorough understanding of the formulation and manufacturing processes. Central to QbD are tools like risk assessment, design of experiments (DoE), and process analytical technology (PAT), which help in identifying and controlling the critical material attributes (CMAs) and critical process parameters (CPPs). Risk assessment techniques, such as failure mode and effects analysis (FMEA), prioritize potential risks in the development process, while DoE enables robust optimization by evaluating multiple variables simultaneously [37]. The integration of QbD into pharmaceutical development offers numerous benefits. By promoting a deeper understanding of product and process parameters, QbD facilitates the design of robust, high-quality formulations that meet patient needs. It reduces variability in production, enhances product consistency, and minimizes the risk of batch failures. Moreover, the proactive nature of QbD allows for more efficient troubleshooting and continuous improvement throughout a product's lifecycle. These advantages not only enhance the therapeutic performance of drug products but also lead to cost savings and streamlined development timelines [38-39]. Regulatory perspectives on QbD further highlight its importance in the pharmaceutical industry. International guidelines, such as ICH Q8 (Pharmaceutical Development), Q9 (Quality Risk Management), and Q10 (Pharmaceutical Quality System), emphasize the implementation of QbD principles to ensure product quality and regulatory compliance. ICH Q8 focuses on the systematic development of formulations using QbD, while Q9 provides a framework for risk management throughout the drug's lifecycle. ICH Q10 outlines the quality systems required for continual improvement in manufacturing and development processes. Regulatory agencies encourage





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QbD to foster innovation, enhance patient safety, and improve manufacturing reliability [40-43]. By embedding QbD into pharmaceutical research, companies can create innovative, patient-centric drug products with higher efficiency and reliability. The application of QbD in sublingual antihypertensive tablet development ensures the creation of formulations that address both clinical needs and regulatory expectations, paving the way for improved therapeutic outcomes and patient care. Figure 01 Represent quality by design approach for Pharmaceutical Product[44].

Implementation of QbD in Sublingual Antihypertensive Tablets

The application of Quality by Design (QbD) principles in the development of sublingual antihypertensive tablets is crucial to ensuring high-quality, effective, and robust formulations. The process begins with the identification of Critical Quality Attributes (CQAs), which are the key physical, chemical, or biological properties that must be controlled to ensure the drug product's safety, efficacy, and quality. For sublingual antihypertensive tablets, CQAs include disintegration time, dissolution rate, bioavailability, stability, and sensory qualities such as taste. These attributes are critical because they directly influence the drug's onset of action, release profile, and overall effectiveness in managing blood pressure. Disintegration time, for example, must be rapid to ensure quick absorption, while the dissolution rate determines how fast the drug enters the bloodstream, which is essential for acute conditions like hypertensive crises [45-46]. Once CQAs are defined, the next step involves selecting Critical Material Attributes (CMAs) and Critical Process Parameters (CPPs). CMAs refer to the raw material properties that affect the final product's quality. In the case of sublingual antihypertensive tablets, CMAs include the particle size of the active pharmaceutical ingredient (API), the solubility of the drug, and the moisture content of excipients. The excipient selection is particularly important as it impacts disintegration time, stability, and the bioavailability of the drug. Similarly, CPPs are the variables in the manufacturing process that need to be controlled to ensure the CQAs are met. For sublingual tablets, CPPs such as compression force, granulation method, and drying parameters must be optimized to achieve the desired tablet hardness, dissolution, and stability. Figure 02 represent risk assessment Matrix for Sublingual tablet [47-50]. Design of Experiments (DoE) is an essential tool in QbD to systematically optimize the formulation and manufacturing process. DoE allows for the efficient evaluation of multiple formulation variables simultaneously, helping identify the most effective combination of excipients, tablet hardness, and disintegration conditions that will achieve the desired drug release and bioavailability. For instance, in the development of sublingual antihypertensive tablets, DoE can help determine the optimal disintegrant concentration and compression force that will ensure rapid dissolution and effective drug delivery. This approach reduces variability, enhances the reproducibility of the formulation, and accelerates the optimization process [51-53]

Challenges and Future Directions

The implementation of Quality by Design (QbD) in pharmaceutical development, particularly for sublingual antihypertensive tablets, presents several technical and regulatory challenges. One of the key technical challenges is the complexity of defining and controlling Critical Quality Attributes (CQAs) such as dissolution rate and bioavailability. Achieving rapid disintegration and dissolution for sublingual formulations requires a detailed understanding of material properties, manufacturing processes, and the interactions between the drug and excipients. Additionally, optimizing these parameters through the use of Design of Experiments (DoE) can be resource-intensive, requiring sophisticated equipment and expertise to ensure the reliability and consistency of results. From a regulatory perspective, while QbD is increasingly recognized and encouraged, its implementation can be difficult due to the evolving nature of guidelines and the need for close collaboration between pharmaceutical companies and regulatory bodies. The transition from traditional batch testing to a more comprehensive, real-time monitoring system, using tools like Process Analytical Technology (PAT), also poses challenges in terms of cost and regulatory acceptance [54]. Emerging trends in sublingual drug delivery and QbD applications point to significant advancements in the field. The development of new excipients, such as fast-dissolving agents and bio-enhancers, is improving the speed and efficiency of sublingual drug release. Furthermore, innovations in nanoformulations and solid dispersion technologies are enhancing drug solubility and absorption, especially for poorly soluble antihypertensive agents. In the context of QbD, the use of advanced modeling and simulation tools is gaining traction, enabling more precise prediction and control over the formulation and manufacturing processes. Additionally, the integration of real-time monitoring through PAT and continuous manufacturing techniques is



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becoming more feasible, providing the ability to control quality attributes throughout the production cycle, ensuring consistency and reducing risks associated with batch-to-batch variation [55]. Looking ahead, the future of antihypertensive sublingual formulations holds great promise, driven by the evolving landscape of QbD and innovative drug delivery technologies. The need for rapid, effective, and patient-friendly treatments for hypertensive emergencies will continue to propel the development of sublingual formulations. There is potential for personalized medicine, where formulations can be tailored to individual patients based on their specific needs, genetic profiles, or response to treatment. Advances in nanotechnology, 3D printing, and biocompatible polymers could further enhance the efficacy and patient compliance of sublingual antihypertensive tablets. Moreover, as regulatory bodies continue to embrace QbD, the approval processes may become more streamlined, providing faster access to market for innovative sublingual therapies. In conclusion, while challenges remain, the future of sublingual antihypertensive formulations, guided by QbD principles, promises to deliver more efficient, patient-centric solutions for managing hypertension [56].

CONCLUSION

Combining sublingual drug delivery with Quality by Design (QbD) principles represents a significant advancement in pharmaceutical development, particularly for antihypertensive therapy. By leveraging QbD, the development of sublingual formulations can be optimized to ensure that critical quality attributes, such as rapid disintegration, dissolution, and bioavailability, are consistently met. This approach allows for the creation of robust, high-quality formulations that not only meet regulatory standards but also enhance the therapeutic performance of antihypertensive drugs. The use of QbD tools like Design of Experiments (DoE) and risk assessment ensures that the formulation and manufacturing processes are thoroughly understood and controlled, leading to improved consistency and reduced variability. The impact on hypertension management and patient care is profound. Sublingual antihypertensive tablets, when developed using QbD, offer the advantage of rapid onset of action, which is crucial in emergency situations such as hypertensive crises. The ease of administration, coupled with improved bioavailability and faster drug absorption, enhances patient compliance and satisfaction. Furthermore, the ability to design personalized, patient-centric formulations opens up new avenues for more targeted and effective hypertension treatments. In conclusion, the integration of sublingual drug delivery with QbD principles has the potential to revolutionize hypertension management, ensuring that patients receive safer, more efficient, and faster-acting treatments, ultimately improving their quality of life and clinical outcomes.

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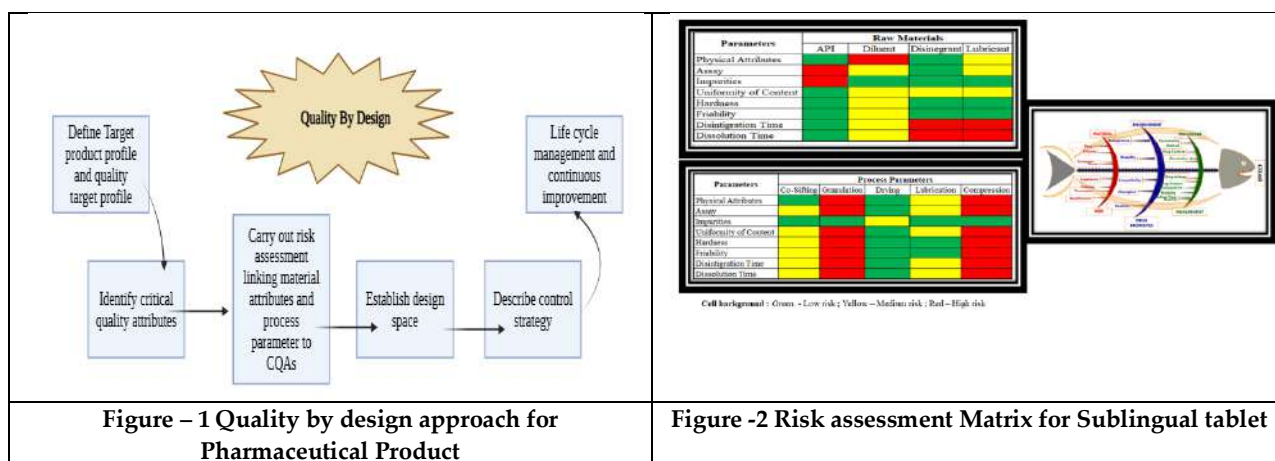
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Immediate Effect of Dynamic Stretching and Active Release Technique (ART) on Sit and Reach, in a Patient with Calf and Hamstring Tightness –A Comparative Interventional Study

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ABSTRACT

Flexibility is a very important physiological component of physical fitness required for our daily activity or for athletic events. If there is reduction in flexibility then it can cause inefficiency at workplace and can be a risk factor for the various conditions like muscle strain during sports, lower back pain, knee pain etc. Tightness of muscle can affect activities of daily living (ADL) of an individual. There are many methods available to measure the muscular tightness, one of the methods for identifying the flexibility of the muscle of lower limb muscle is by performing the sit and reach test. By using this test, it can be identified if the muscle tightness is present and also post treatment improvement in flexibility can be noted. To improve flexibility stretching can be useful, methods like static stretching, dynamic stretching etc. can be given also manual techniques like active release technique (ART), positional release technique can be useful. So, aim of this study is to compare immediate effect of Dynamic Stretching and ART To study and compare the effect of active release technique and sit and reach on subjects with calf and hamstring tightness. The subjects fulfilling selection criteria were selected between the age of 18-30 years, then they were randomly divided in to either of two groups (Dynamic Stretching or ART). Before giving the intervention analysis of flexibility by sit and reach test was done. The intervention was given for both hamstrings and calf muscles in the form of active release technique or the dynamic stretching. Then post evaluation for Calf and Hamstring tightness by sit and reach test was done. The statistical analysis shows that there is a significant improvement (P value <0.05) in flexibility when analysis is done within group using paired t - test in both the groups. But there was no significant difference between both the interventions when analysed using unpaired t test. This study concludes that individual receiving



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dynamic stretching and active release techniques both techniques is equal effectiveness on calf and hamstring tightness in sit and reach test.

Keywords: Dynamic stretching, Active Release technique, Sit and Reach test, Flexibility.

INTRODUCTION

Flexibility is a very important physiological component of physical fitness required for our daily activity or for athletic events. [1] If there is reduction in flexibility then it can cause inefficiency at workplace and can be a risk factor for the various conditions like muscle strain during sports, lower back pain, knee pain etc. [2] The ability of an individual to move smoothly depends on his flexibility, an attribute that enhances both safety and optimal physical activities. [3] There are various causes for limitation in flexibility like sex, joint type, extensibility of tendons and ligaments, and muscle relaxation ability. [3] Hamstring tightness is reportedly associated with a posterior rotation of the pelvis in standing. [3] A posterior rotation of the pelvis tends to flatten the lumbar spine, which may increase the risk of low back pain. [3] Gastrocnemius tightness results in a significant increase in knee flexion at initial contact and mid-stance. Continuity and development of flexibility is ensured by stretching exercises. Numerous stretching techniques have been developed, reported and applied by physical therapists, coaches and athletic trainers for improving ROM as well as for warm-up purposes. [4] Dynamic stretching (DS) – Low-intensity active stretching, using repeated, short-duration, end-range active muscle contractions of the muscle opposite the shortened muscle are a form of self-stretching exercise [4] Active release technique (ART) is a manual therapy for treating soft tissue problems in muscles, joints, and connective tissue. [5] Active Release Technique is based on the theory of cumulative trauma disorder (CTD). CTD is a soft tissue injury that results from acute injury, repetitive injury, or a constant pressure/tension injury. [6] The active release technique (ART) is a treatment method used for soft tissue injuries of muscles and myofascial that cause mechanical dysfunction, which can lead to pain and muscle weakness. [4] Long duration sitting is a contributory factor for developing tightness. [7] Flexibility dysfunction is a widespread problem faced by common people as well as sportspersons, especially in case of hamstring group of muscles. A tight gastrocnemius (with increased compensatory pronation) also predisposes patients to plantar fasciitis. The need of the study is to identify the effective technique to reduce the tightness of the muscle. [7]

METHODS

This study was conducted in and around Rajkot city, ethical permission was taken from departmental ethical committee. Total 30 subjects were selected who would fulfil the criteria of selection. Criteria for selection were [8]: inclusion criteria – Individuals between 18-30 years age, Male and Female both, Calf and hamstring both muscles tightness should be present. Exclusion criteria - History of previous lower limb injury or pain from past one year, history of fracture or surgery of back, pelvis, hip, knee or ankle from past one-year, inflammatory condition that could affect motion, Spinal deformity or any neurological condition. After proper explanation about the purpose and procedure of the study, individuals who participate in this study were requested to sign a written consent form. The selection of participants was done by convenient sampling and then randomly divided into either of the two groups by odd and even number into either Group – A DS and Group – B ART. After proper explanation about the purpose and procedure of the study, individuals who participate in this study were requested to sign a written consent form. A pre-participation evaluation form consisting of basic assessment chart was filled which included name, age, gender, occupation, address, and Range Of Motion (ROM) and sit and reach test. For Group – A: Dynamic Stretching exercises were given for both hamstring and calf muscles 15 repetitions were given. For Hamstrings muscle (Figure 1): The subject contracted the hip flexors with knee extended and flexed the hip joint so that the leg swung forwards to the anterior aspect of his body i.e. front kick through the active ROM of the hip joint. For calf muscle (Figure 2) – Step forward with one leg and keep back heel flat on the ground while knee was flexed. Contraction of quadriceps and tibialis anterior muscles to extend back knee. At the same time, move forward to the point of mild stretch on the back





calf muscle and then immediately release i.e., forward lunge. [9] For Group B – ART: For ART Subjects lie supine on the plinth and gentle tension is applied to the hamstring muscle along the entire length (longitudinal length) while stretching the leg in different positions to better work the muscle, then palpate the taut band. Then individual was asked to perform movement for 15 times. [10] For calf muscle subject was in prone lying position with the knee flexed to 90 degree and the ankle maintained in plantarflexion. Therapist applied deep manual pressure on the trigger point and while sustaining it the subject actively extended the knee as well as dorsiflexed the ankle 15 repetitions were performed (Figure 3). [11] Following intervention post data for V sit and Reach test was taken and statistical analysis was done.

RESULTS

The result of current study analysis was done by Statistical Package for the Social Sciences (SPSS). Data of test are of interval/ratio type, and normality was followed according to Shapiro-willk test. So parametric test was applied. Intra-group comparison was done by applying Paired t- Test and inter group comparison between both the group was done by Unpaired t- Test. Analysis shows that there is a significant improvement in flexibility when analysis is done within group using paired t- test in both the groups (Table-1&2). This suggests that there both the techniques are helpful for improving flexibility. When comparison is done between the effectiveness of two techniques, it has been identified that there is no significant difference between them (Table-3). This suggests that both techniques can improve the flexibility equally

DISCUSSION

The purpose of this study was to find the effective treatment for improving flexibility by assessing through sit and reach test performance between DS and ART. According to the analysis both group shows improvement in flexibility. But when compared between two groups both shows equal improvement when flexibility is evaluated by Sit and Reach test performance. The effects of DS component for increase in ROM post intervention can one possible effect of an elevated muscle temperature resulting from dynamic stretching is a decrease in muscle viscosity. [12] It is reported that passive stiffness decreased following dynamic stretching, also it has been proposed that an increase in temperature may decrease the viscous resistance of muscles and by consequence enhance tissue extensibility. [12] One of the research article also found that DS caused a sustained reduction in passive stiffness of the hamstrings and increase in knee ROM, as well as a less lasting increase in passive torque at the onset of pain. As increased passive stiffness of the hamstrings and decreased knee ROM are both risk factors for hamstring injury during sports. [13] Another study done by Kaushik on immediate effect of active release technique (ART) versus muscle energy technique (MET) on hamstring tightness in sewing machine operators. concluded that Active Release Technique (ART) is more effective than Muscle Energy Technique (MET) in reducing hamstring tightness immediately. [14] Another study done by Jain NM, Zore L, Kumar A. on comparison of active release technique and positional release therapy for gastrosoleus trigger point release in recreational runners, concluded that there was a significant increase in the ankle dorsiflexion range of motion following ART, but PRT shows better improvement by reducing pain. [11] Both of these articles support our findings that ART can improve flexibility, the possible mechanism by which ART improves pain could be because of breaking the cross-fibre adhesions which restricts the smooth movement of tissues by adhering to adjacent tissues. [11]

CONCLUSION

This study concludes that individual receiving dynamic stretching and active release techniques both techniques is similar effectiveness on calf and hamstring tightness in sit and reach test. Hence any technique can be useful for improving flexibility in clinical practices.



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Table.1: shows within group comparison of sit and reach test by Dynamic Stretching

GROUP A	Mean	Std. Deviation	P value
Pre data of Sit and reach test	32.93	7.554	0.000
Post data Sit and reach test	40.40	6.243	

Table.2: shows within group comparison of sit and reach test by Active release technique

GROUP B	Mean	Std. Deviation	P - value
Pre data of Sit and reach test	36.67	14.201	0.000
Post data Sit and reach test	41.87	13.043	



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Table.3: shows comparison between both the techniques as the p value is more than 0.05, analysis suggest no significant difference between the efficacy of both the technique

Between Group Analysis	Mean	Std. Deviation	P – value
GROUP A	7.47	3.720	0.142
GROUP B	5.20	4.459	



Figure.1:Dynamic Stretching of hamstring



Figure.2:Dynamic Stretching of calf muscle



Figure.3:Active release technique for calf muscle





Just the Tip of the Iceberg: Nutritional Assessment and Management of Hyperglycemia during Carcinoma of Stomach – A Case Report

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ABSTRACT

Stomach cancer mortality continues to account for a substantial proportion of the total number of cancer-related deaths. The majority of those with advanced cancer suffer from cancer anorexia-cachexia syndrome, which includes weight loss, a loss of appetite, exhaustion, and weakness. Undernutrition is frequently observed in stomach cancer patients. Nutrition should be a significant and mandatory aspect of complex treatment in cachectic individuals with stomach cancer. Nutritional support should be provided to patients before, during and after surgery. Maintaining proper nutritional intake while undergoing active treatment might be difficult for cancer patients. Poor nutrition is exacerbated by nausea, anorexia, and alterations in smell and taste. Thus, adequate nutrition before, during and after cancer treatment can help patients to improve survival rate, prevent the onset of malnutrition and enhance morbidity. Here, we report a case of gastric cancer in a 36-year-old male who came with complaints of vomiting for the last forty days within half an hour of eating food which is bilious in nature and contains food particles. He was a known case of T2DM and HTN for seven years and was on regular medications.

Keywords: Gastric Cancer, Malnutrition, Nutritional Support





INTRODUCTION

Stomach cancer, also known as gastric cancer, arises from the lining of the stomach and is often associated with various risk factors including *Helicobacter pylori* infection, dietary habits (e.g., high salt intake, consumption of smoked foods), smoking, and genetic predisposition. It is a significant health concern globally, particularly in East Asia, with symptoms often including indigestion, stomach pain, nausea, and weight loss [1]. Hyperglycemia, or high blood sugar levels, is a condition commonly seen in cancer patients. This can be due to various factors such as the stress response to cancer, side effects of cancer treatments like chemotherapy or steroids, and underlying conditions such as diabetes. Uncontrolled hyperglycemia in cancer patients can complicate treatment, affect the patient's prognosis, and diminish quality of life [2]. Nutrition plays a critical role in the management of both gastric cancer and hyperglycemia. For gastric cancer patients, maintaining adequate nutrition can be challenging due to symptoms like nausea, vomiting, and early satiety. Proper nutritional support is essential to maintain body weight, strength, and immune function, which are crucial for tolerating cancer treatments [3]. In the context of hyperglycemia, nutritional strategies become even more complex. Managing blood glucose levels through diet involves balancing carbohydrate intake, monitoring glycemic indices of foods, and ensuring adequate nutrient intake to support overall health and cancer treatment efficacy. Key aspects include Dietary Modifications such as incorporating low glycemic index foods, spreading carbohydrate intake throughout the day, and avoiding sugary and high-carbohydrate foods; Monitoring and Adjustment like regular monitoring of blood glucose levels to tailor dietary recommendations and adjustments in response to fluctuations and Multidisciplinary Approach like collaboration between oncologists, dietitians, endocrinologists, and other healthcare professionals to create a comprehensive care plan that addresses both cancer treatment and glucose management [4].

CASE REPORT

A 36-year-old male came with complaints of vomiting for the last forty days within half an hour of eating food which is bilious in nature and contains food particles. He was a known case of T2DM and HTN for seven years and was on regular medications. On the third day of hospital admission the patient underwent USG, Endoscopy and Biopsy which revealed a tumor of three centimeters in fundus region of the stomach, requiring partial Gastrectomy followed by Chemotherapy. Nutritional assessment was done using GLIM Criteria, Phenotypic [Figure 1], [Figure 2] and Etiologic criteria [Figure 3], [Figure 4] were assessed. Nutritionally diagnosed to be moderately malnourished, with anemia and hyperglycemia, as evidenced by weak handgrip strength, anorexia, early satiated and suboptimal food and nutrient intake and blood sugar levels. Medical Nutrition Therapy initiated with energy and protein recommendations set at 30 kcal/kg/IBW and 1.2g/kg/IBW based on ESPEN 2021 dietary guidelines during cancer [5]. Oral Diet initiated on POD 4 and progressed in consistency from liquid to normal based on tolerance. Oral Nutrition Supplement meeting 35% of estimated requirement was provided and tapered according to improvement in oral intake.

DISCUSSION

It is advisable for cancer patients to be screened regularly for risk of malnutrition. Adequate nutrition before, during and after cancer treatment can help patients to improve survival rate, prevent the onset of malnutrition and enhance morbidity. In this case at the time of discharge the phenotypic status improved to normal as evidenced by improvement in Handgrip Strength and the etiologic status improved to normal food intake as evidenced by improvement in nutrient intake. Thus, appropriate assessment of nutritional status using the GLIM Criteria, coupled with timely nutritional intervention, counseling and monitoring improved patient outcome as evidenced through improved nutritional parameters, glycemic control and length of hospital stay. Several studies support the recommendation that cancer patients should be regularly screened for malnutrition to improve their outcomes. Research by Arends et al. (2017) highlights that nutritional support is essential before, during, and after cancer treatment to enhance survival rates and prevent malnutrition [6]. Similarly, a study by Cederholm et al. (2019) confirms that assessing nutritional status using the Global Leadership Initiative on Malnutrition (GLIM) criteria,



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which includes parameters such as Handgrip Strength and nutrient intake, is effective in identifying malnutrition and guiding interventions [7]. A comprehensive review by Laviano et al. (2018) indicates that timely nutritional interventions and counseling significantly improve nutritional parameters, glycemic control, and reduce hospital stay length [8]. These findings correlate well with the case discussed, where the patient's phenotypic and etiologic statuses improved to normal, demonstrating the effectiveness of early and ongoing nutritional assessment and intervention.

CONCLUSION

Individualized Nutritional Support with continuous monitoring and counseling resulted in significant improvement in nutritional status, as evidenced by an improved Malnutrition Universal Screening Tool (MUST) score and enhanced Handgrip Strength (HGS). The tailored dietary interventions were meticulously designed to meet the specific nutritional deficiencies of the patient. Regular evaluations and adaptive modifications based on ongoing assessments facilitated timely and effective interventions. This comprehensive support system not only optimized physiological health markers but also positively influenced the patient's overall well-being and functional capacity.

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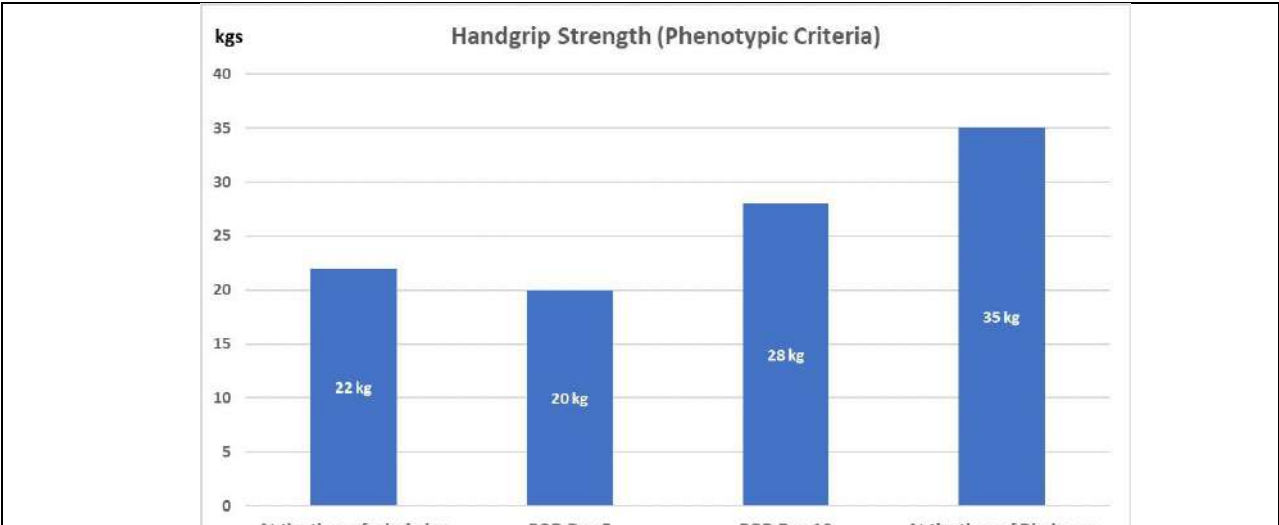


Figure 1: Handgrip Strength

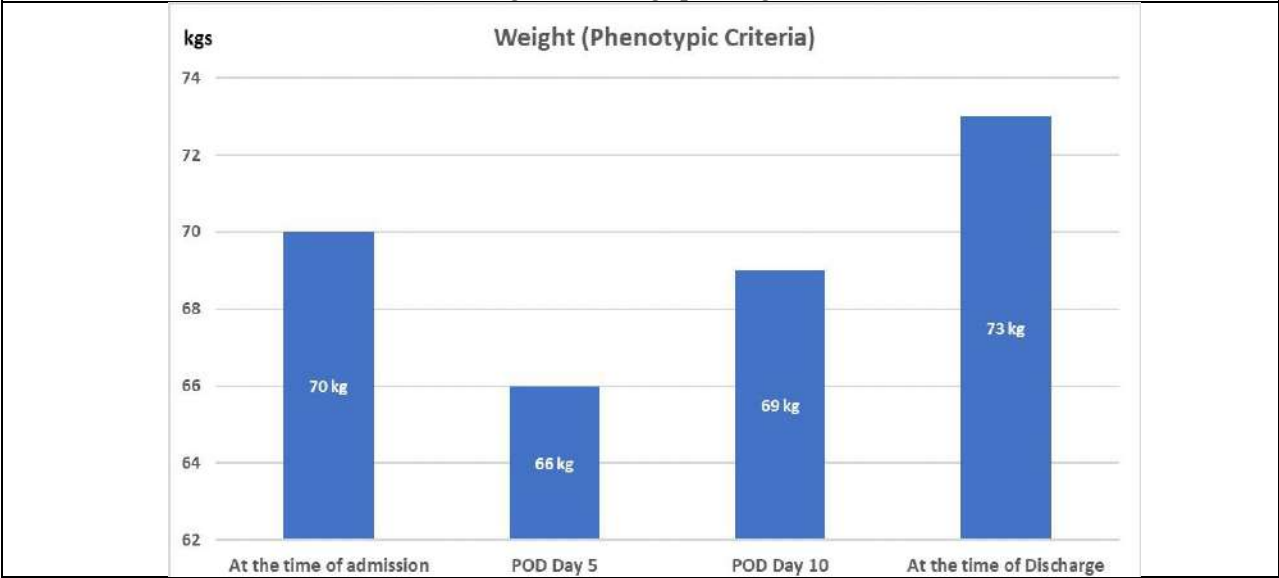


Figure 2: Weight





Soma Basu and Hemamalini

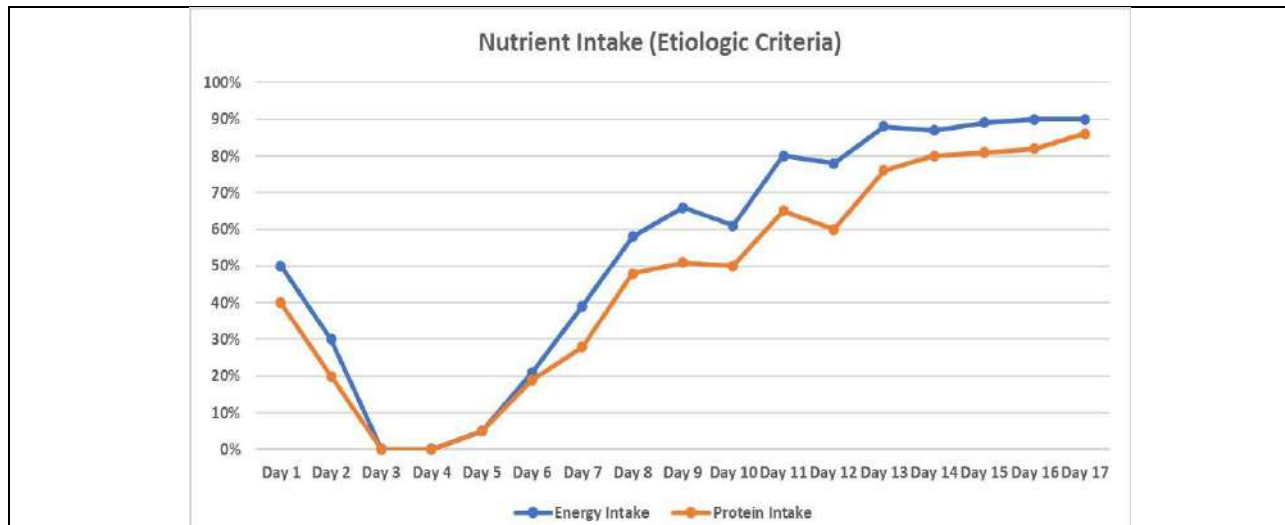


Figure 3: Nutrient Intake

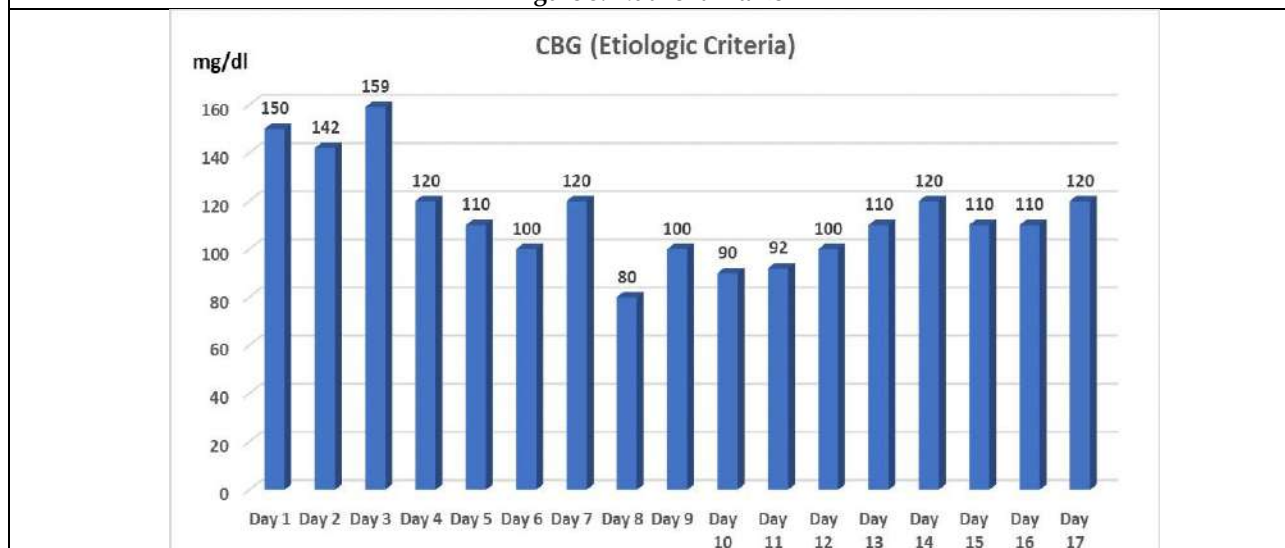


Figure 4: CBG Levels





Literary Comparative Analysis of Cow, Goat, and Buffalo Curd: Ayurvedic Perspectives on Nutritional Composition and Therapeutic Potential

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ABSTRACT

This study presents a comparative analysis of curd derived from cow, goat, and buffalo milk, focusing on Ayurvedic perspectives regarding nutritional composition and therapeutic potential. Using established Ayurvedic principles, including Rasa (taste), Virya (potency), and Vipaka (post-digestive effect), the nutritional profiles of curd from different animal sources were evaluated. Additionally, therapeutic properties such as Grahi (constipative), Dhatusarata (tissue nourishing), and JatharagniBalapravritti (enhancement of digestive fire) were assessed. Results revealed distinct variations in nutritional composition and therapeutic attributes among cow, goat, and buffalo curd. Cow curd exhibited predominance in Sattvic properties, while buffalo curd demonstrated Rajasic characteristics. Furthermore, goat curd displayed a balance of Sattvic and Rajasic qualities. The study underscores the importance of considering animal source variability in curd production for optimizing its therapeutic potential according to Ayurvedic principles.

Keywords: Curd, Cow, Goat, Buffalo, Ayurveda, Nutritional Composition, Therapeutic Potential, Rasa, Virya, Vipaka, Grahi, Dhatusarata, JatharagniBalapravritti, Sattvic, Rajasic.



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INTRODUCTION

According to Ayurveda, balance of Dosha, Agni, Dhatu and Mala is called as Health. There are three pillars to maintain this equilibrium, Aahara, Nidra and Bramhacharya. Now a day, Aahara and Vihara of people is not in a proper direction. People are adopting western food culture leaving the traditional food pattern. The consumption of Dadhi without following the rules of Ayurved has also increased nowadays. Regarding this, different methods of consumption that have been seen in consumption of Dadhi. This result in increased occurrence of diseases. The consumption of curd, a staple in many cultures worldwide. In the realm of Ayurveda, an ancient system of medicine originating from the Indian subcontinent, curd holds a significant place due to its perceived therapeutic properties. This research endeavours to conduct a literary comparative analysis focusing on the nutritional composition and therapeutic potential of curd derived from three distinct sources: cow, goat, and buffalo milk. By delving into Ayurvedic perspectives, this study aims to elucidate the unique attributes of each type of curd, exploring their respective roles in promoting health and well-being according to traditional wisdom. Through this comparative lens, we seek to contribute to in detail knowledge of the nutritional and medicinal aspects of curd consumption, offering insights that may inform dietary practices and healthcare strategies in both traditional and contemporary contexts.

Literature Review

Ayurvedic Perspectives on Curd

Ayurveda, an ancient system of medicine originating in India, classifies Aahar depend on their effects on the body's doshas. Each type of curd is believed to possess unique properties that influence its therapeutic uses:

Cow Curd (GoDadhi)

- **Qualities (Gunas):** Cooling, heavy, and unctuous.
- **Dosha Impact:** Primarily pacifies vatadosha but can increase kapha and pitta doshas if consumed excessively.
- **Therapeutic Uses:** Recommended for digestive issues, malnutrition, and strengthening the body. It is also believed to promote mental stability and improve complexion.

Goat Curd (AjaDadhi)

- **Qualities (Gunas):** Light, cooling, and astringent.
- **Dosha Impact:** Balances all three doshas but is especially beneficial for pitta and kapha imbalances.
- **Therapeutic Uses:** Known for its digestive benefits, it is less likely to cause congestion compared to cow curd. It is also recommended for patients with respiratory conditions and weak digestive systems.

Buffalo Curd (MahishaDadhi):

- **Qualities (Gunas):** Heavy, cooling, and sweet.
- **Dosha Impact:** Increases kaphadosha and can pacify pitta dosha while having a neutral effect on vatadosha.
- **Therapeutic Uses:** Valued for its nourishing and strength-giving properties. It is often recommended for those needing weight gain, increased muscle mass, and strength. However, it may be contraindicated in conditions where kapha is already aggravated.

Nutritional Composition

Modern scientific analysis complements Ayurvedic knowledge by detailing the macronutrient and micronutrient content of curd:

Cow Curd:

- **Protein:** High-quality proteins with all essential amino acids.
- **Fat:** Lower fat content compared to buffalo curd.
- **Carbohydrates:** Contains lactose, beneficial for gut health due to probiotic content.
- **Vitamins and Minerals:** Rich in calcium, vitamin B12, and riboflavin.



**Goat Curd**

- **Protein:** Easily digestible proteins, suitable for lactose-intolerant individuals.
- **Fat:** Medium-chain fatty acids that are metabolized differently and beneficial for heart health.
- **Carbohydrates:** Lower lactose content, reducing the risk of lactose intolerance symptoms.
- **Vitamins and Minerals:** High in calcium, potassium, and vitamin A.

Buffalo Curd

- **Protein:** Higher protein content compared to cow and goat curd.
- **Fat:** Higher fat content, leading to a creamier texture and more calories.
- **Carbohydrates:** Similar lactose content to cow curd.
- **Vitamins and Minerals:** Rich in calcium, magnesium, and phosphorus.

Therapeutic Potential

The therapeutic potential of curd, as discussed in Ayurvedic texts, is supported by modern research:

Digestive Health

- Probiotic content in curd enhances gut flora, aiding in digestion and preventing gastrointestinal infections.
- Curd's cooling properties help in managing hyperacidity and gastritis.

Nutritional Benefits

- A rich source of essential nutrients, curd helps in maintaining bone health due to its high calcium content.
- The protein in curd is crucial for muscle repair and growth.

Immunomodulatory Effects

- Regular consumption of curd can boost the immune system due to its probiotic content.
- It also helps in reducing inflammation and may have potential benefits in managing autoimmune diseases.

Weight Management

Depending on the type of curd, it can aid in weight gain (buffalo curd) or weight management (goat curd).

Aim

To conduct a comprehensive comparative analysis of cow, goat, and buffalo curd through the lens of Ayurvedic principles, examining their nutritional compositions and therapeutic potentials.

Objectives

- 1) To analyze the nutritional composition of cow, goat, and buffalo curd
- 2) To explore the Ayurvedic properties and classifications of cow, goat, and buffalo curd
- 3) To evaluate the therapeutic potential of cow, goat, and buffalo curd:
- 4) To compare the suitability of cow, goat, and buffalo curd for different health conditions and dietary needs

MATERIAL AND METHODS**Materials****Primary Sources:**

- Classical Ayurvedic texts such as CharakaSamhita, SushrutaSamhita, and AshtangaHridaya for qualitative data on the properties and therapeutic uses of cow, goat, and buffalo curd.

Modern Scientific Literature

- Peer-reviewed journal articles, books, and research reports on the nutritional composition and health benefits of cow, goat, and buffalo curd.



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○ Databases such as PubMed, Google Scholar, and JSTOR for sourcing relevant scientific literature.

Methods

Literature Review

Ayurvedic Literature Review

- Systematic examination of classical Ayurvedic texts to extract information on the properties (gunas), dosha impacts, and therapeutic uses of cow, goat, and buffalo curd.
- Cross-referencing multiple texts to ensure comprehensive coverage and accuracy of Ayurvedic perspectives.

Modern Scientific Literature Review:

- Systematic review of scientific literature on the nutritional composition and health benefits of cow, goat, and buffalo curd.
- Using keywords such as "nutritional composition of cow curd," "therapeutic potential of goat curd," and "health benefits of buffalo curd" to search databases.
- Summarizing findings to provide a modern scientific context to the Ayurvedic properties.

Comparative Analysis

Ayurvedic Comparison:

- Comparison of the Ayurvedic properties of cow, goat, and buffalo curd based on textual evidence.
- Identifying similarities and differences in dosha impacts and therapeutic uses.

Nutritional and Therapeutic Comparison

- Comparative analysis of the nutritional profiles of cow, goat, and buffalo curd.
- Correlating the nutritional data with Ayurvedic properties and therapeutic potentials.

Data Synthesis

- Integrating findings from both Ayurvedic texts and modern scientific literature to provide a holistic understanding of the nutritional composition and therapeutic potential of cow, goat, and buffalo curd.
- Summarizing the results in a comparative framework to highlight key differences and similarities.

Validation

- Peer review of findings by experts in Ayurveda and nutrition science to ensure accuracy and relevance.
- Incorporating feedback and making necessary adjustments to the analysis and interpretation of data.

DISCUSSION

Ayurvedic Perspectives on Curd

The analysis of Ayurvedic texts reveals that cow, goat, and buffalo curd possess distinct properties and therapeutic potentials. Ayurveda classifies foods based on their effects on the body's doshas, Ras, Veerya, Vipaka.

Comparative Analysis

The comparative analysis highlights key differences and similarities in the nutritional composition and therapeutic potentials of cow, goat, and buffalo curd:

Cow vs. Goat Curd

- Cow curd is more suitable for general health and digestive issues, while goat curd is better for those with lactose intolerance and specific respiratory conditions.



**Cow vs. Buffalo Curd**

- Cow curd has lower fat content, making it suitable for a broader population, while buffalo curd is ideal for those needing additional calories and strength.

Goat vs. Buffalo Curd:

- Goat curd is lighter and more easily digestible, while buffalo curd provides higher energy and nourishment, suitable for specific therapeutic needs.

CONCLUSION

The study "Literary Comparative Analysis of Cow, Goat, and Buffalo Curd: Ayurvedic Perspectives on Nutritional Composition and Therapeutic Potential" offers a comprehensive evaluation of the nutritional and therapeutic attributes of cow, goat, and buffalo curd through both Ayurvedic and modern scientific lenses. The findings highlight the unique qualities and health benefits of each type of curd, making them suitable for various health conditions and dietary preferences.

Cow Curd:

- **Ayurvedic Perspective:** Recognized for its cooling and nourishing properties, cow curd is ideal for digestive health, addressing malnutrition, and enhancing mental stability.
- **Nutritional Composition:** Rich in high-quality proteins, calcium, and essential vitamins, it supports bone health and overall wellness. Its lower fat content makes it a versatile choice for the general population.

Goat Curd

- **Ayurvedic Perspective:** Known for its light and easily digestible nature, goat curd balances all three doshas and is particularly beneficial for those with respiratory issues and weak digestion.
- **Nutritional Composition:** High in easily digestible proteins, medium-chain fatty acids, and essential minerals, it is suitable for lactose-intolerant individuals and those with specific dietary needs.

Buffalo Curd:

- **Ayurvedic Perspective:** Valued for its heavy and nourishing properties, buffalo curd is recommended for individuals needing weight gain, increased muscle mass, and overall strength.
- **Nutritional Composition:** With a higher protein and fat content, it provides significant caloric and nutritional value, though it may not be suitable for those managing weight or with kapha imbalances.

The integration of Ayurvedic knowledge with modern nutritional science underscores the therapeutic potential of curd as a functional food. Each type of curd offers distinct benefits, making them appropriate for different health conditions and dietary preferences. Future research should focus on identifying specific bioactive compounds in curd that contribute to its therapeutic effects, further bridging traditional Ayurvedic practices and contemporary health science. This holistic understanding can enhance dietary recommendations and promote the use of curd in therapeutic diets globally.

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Appraisal of Feasibility of BRTS Route in Lucknow

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ABSTRACT

Mobility is accessibility—the ability to go from one location to another in a secure, safe, economical, and convenient manner. Commuters should have arrived at their destination within a set amount of time. Transportation is meaningless without mobility. On a trip, one should have a variety of high-quality transportation options. One should have transportation options for their trip, as well as quality of it. To improve one's mobility should be the aim of any transportation. [1] The aim of this research paper is to check the feasibility of the BRTS route in Lucknow. The study has been done on the selected route to assess its feasibility based on factors like: Population served, Passenger per hour per direction (PPHPD) and availability of right of way (ROW), feeder service, user satisfaction, ridership, and landuse pattern. Inferences are drawn from analyzing the survey data to find out the gap and formulate the final proposal.

Keywords: Bus Rapid Transit System, Passenger demand, Right of Way, Passenger per hour per direction, Ridership, Feeder service.

INTRODUCTION

According to a UN estimate from 2014, almost 54 % of the world's population lives in urban areas. This figure is expected to rise to 66 % by 2050. The workforce frequently uses public transport for commuting, which increases the chance for traffic congestion. Congestion in public transportation systems has become a point of concern in many

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parts such as New Delhi, Mumbai, and others, and it must be handled on an urgent note. Insufficient parking spaces, lack of pedestrian facilities, last mile connectivity, feeder services, encroachment on road, lack of traffic signals are the main issues which affect BRTS. The Platform level boarding, Bus way alignment, Intersection treatments and Off-board fare collection are important considerations for the effective implementation of BRTS. BRTS is a dedicated Right of Way (ROW) on a major arterial road. BRTS delivers comfortable, fast and cost-effective services and carries a large number of passengers along it. BRTS is a public transportation system that prioritizes its customers and is of the highest quality, capacity, and speed.

Literature Study

The BRT Standard is an evaluation tool for BRT routes based on international best practices. BRTS Ranking is done on BRT Standard and have been scored, verified by The BRT Standard Technical Committee by Institute for Transportation & Development Policy. The BRT Standard Technical Committee evaluates BRT Corridor on the five parameters i.e. BRT Basics (38 points), service planning (19 points), infrastructure (13 points), stations (10 points), communication (5 points) and access & integration (15 points). [2] Based on these parameters, BRT standard ranking will be done and is defined in three class Gold (above 85 points), Silver (70-84.9 points) and Bronze (55-69.9 points). [2] For case study, BRT corridor (routes) of three cities i.e., Surat, Ahmedabad and Pimpri Chinchwad has been taken for analysis and also done the comparative analysis of it on the basis of BRT Standard. The corridors which are selected for the following cities

- a) Ahmedabad BRTS (Janmarg Ltd.): Narol – Naroda, [3]
- b) Surat BRTS: Udhna Darwaja – Sachin Gidc [4] and
- c) Rainbow BRTS (Pimpri Chinchwad): Sangvi Phata– Kiwale.[5]

As per the BRTS ranking, Ahmedabad (2013) scores silver: 72 points, Surat (2014) scores bronze: 58 points and Pimpri Chinchwad (2016) is below the BRT ranking and scores only: 43 points. [6] Ahmedabad BRTS scores the highest points because of the high-quality customer-oriented services, infrastructural services, easy and affordable trips, ITS technology, modal share of buses is high i.e. 12%. [7] Surat BRTS scores second highest points because it provides quality customer-oriented services, easy and affordable trips, ITS technology, Surat's BRT is not so successful as compared to Ahmedabad's as Surat shares modal bus share which is only 1 %, ridership is increasing [8] due to quality services and its BRT coming into recognition, people are majorly dependent on three-wheeler public transport. [9] Pimpri Chinchwad BRTS scores the lowest points because there is no provision for ITS technology (proposed), provides ticketing system and shares only 2 % of the modal bus service. [10] The BRT of Pimpri Chinchwad is not successful as compared to Ahmedabad and Surat. Pimpri-Chinchwad is developing, so there is a scope for BRT in the future.

Study Area And Analysis of Study Area**Introduction**

Lucknow is the capital of Uttar Pradesh, is the largest state of India in terms of population. Lucknow is situated at the heart of Uttar Pradesh and is surrounded by Barabanki on east side, Raebareilly on south side, Unnao on west side and Hardoi and Sitapur on north side. Lucknow district is divided into five sub districts i.e., Bakshi ka talab, Malihabad, Mohanlalganj, Sadar and Sarojani nagar. It consists of eight Nagar Panchayat, one Cantonment Board and one Municipal Corporation. Population of Lucknow as per census 2011 is 2,817,105 and as per United Nations, World population prospects 2022 is 3,854,224. Modal share in Lucknow for year 2010-Private vehicle 80%, Intermediate public transport 16%, Public transport 4% whereas for 2031 that is projected for Private vehicle 64%, Intermediate public transport 6% and Public transport 30 %. Therefore, the share for public transport will increase from 4% to 30%, resulting in high ridership for BRTS in the future. [11] Study area lies within Lucknow Municipal Corporation boundary having an area of 348 Ha.

Analysis of study area

The Lucknow city has fulfilled all the basic requirements to run a BRTS stated herewith





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Population- Population of Lucknow as per census 2011 is 2.8 million and as per United Nations, World population prospects 2022 is 3.8 million

Passenger demand in PPHPD

Passenger demand in PPHPD (Passenger per hour per direction) has been analysed at various junctions. The junctions selected for ground survey includes:

- Bithauli Crossing – BC: 6560 pphpd
- Engineering College Chauraha – ECC: 6120 pphpd
- Kanchana Bihari Marg – KBM: 6179 pphpd
- Scetor-25, Indira Nagar – SIN: 6232 pphpd
- Munshipulia – MU: 6708 pphpd
- Polytechnic Chauraha – PC: 7015 pphpd

Three surveys were conducted from jan 2022 to mar 2022 for analysis:

- 1.Reconnaissance Survey & Landuse Analysis
- 2.Origin-Destination Survey
- 3.Traffic Volume Count

Inference of Reconnaissance Survey & Landuse Analysis

Reconnaissance survey is done for Landuse analysis along BRT Corridor. A buffer of 500 metres on both sides has been taken as a study area for the analysis of the BRT Corridor. [Map 1] Commercial areas are identified along the BRT corridor, which is 10.53% of the study area. Commercial activities attract a greater number of people for job opportunities as it also attracts commuters for their needs. Public/semipublic areas comprises 10.53% of the study area. IET College and polytechnic attracts educational trips. Major Trips originate from Residential areas (64%) such as Kalyanpur, Indira nagar, Vikas nagar, Khurram nagar, Aziz nagar, Ishwarpuri, Bhagwatipuram, Aliganj etc which consist of 63.99% of study area. Recreational areas include Swarn Jayanti Smriti Vihar Park along a corridor that results in recreational trips. Transportation consists of 7.66% of study area which also include railway track along a Bithauli crossing. The Industrial area consists of HAL which is 1.48% of the study area.

Analysis of Origin-Destination Survey

Origin-destination (O-D) surveys provide a detailed analysis of trip patterns and travel choices of a city's commuters, origin and destination of various vehicles, user satisfaction while travelling and feeder services. For origin-destination survey, 200 commuters have been taken for analysis in which the maximum number of trips is for work, followed by education, recreation, shopping, and lastly, health. The mode of travel used for these trips are 2-wheeler which is 52% of total sample taken, followed by 4 wheeler which is 24%, then auto which is 20% and lastly bus which is 4% of total sample taken as shown in Figure 1

Inference of OD Survey

Maximum number of trips are generated in the study area due to (fig 2)

- **Educational Trip** shares second major of all trips generated. The reason is several educational and research institutes are situated along the study BRTS route e.g. Integral University, Engineering college, Polytechnic & IIM
- **Work Trip** shares the major proportions of all trip generated especially towards Gomtinagar, Polytechnic, Indira nagar, Nishatganj, Hazratganj, Charbagh, Bithauli, BKT, Madiyaon etc.
- **Health Trip** – Availability of various hospital on ring road such as Jagrani hospital, Regency Multispeciality hospital etc
- **Shopping Trip** – At Bhoothnath market, Wednesday (weekly market), Tedhi pulia, Kapoorthala market etc. Commercial development along ring road

Inference of Traffic Volume Count (TVC) survey

Traffic Volume Count survey (TVC) has been done to analyze Level of Service (LOS) of the road, traffic congestion, carrying capacity, Volume capacity Ratio, to determine peak hour, average daily traffic (ADT) and ridership scenario.





Private vehicles i.e., 2 & 4 wheelers are the most prevalent mode of transportation in this corridor, followed by public transportation. The Average speed at the junctions is 32 km/h. The Volume capacity ratio is more than 1 and the Level of Service is D, which results in severe congestion at junctions in peak hours. As a result, BRTS can be used to shift the mode from private vehicles to public transportation, particularly BRTS. A dedicated bus lane on the BRTS would reduce traffic and provide a more friendly environment. The majority of people commute by 2-Wheeler, then 4-Wheeler, and lastly by auto. Bus usage is really low as the frequency of buses is 15-20 minutes. The maximum Traffic flow in PCU/Hr is 1968 at Polytechnic. The average vehicular composition of study area is 2-Wheeler which is 54% & 4-Wheeler which is 27%. Auto which is 12% and Bus & HCV is 1%. Cycle which is 3% of study area as shown in figure 3. The shift from private vehicles to public transportation is much needed because it will reduce the hazardous impact on the environment while also making the trip more affordable.

Regional and Intra City Connectivity

Existing bus routes are identified to know the best suited route for BRTS as shown in Map 1 [12] Existing metro routes are identified in order to provide feeder services through BRTS as shown in Map 2 [13] The main aim of BRTS is to complement MRTS rather than to compete with it because they both have different characteristics. Identified corridor length for different corridor are as follows: Corridor 1 (Dubagga station to Bithauli Crossing)– 12 Km, Corridor 2 (Bithauli crossing to Polytechnic chauraha) – 12 Km, Corridor 3 (Polytechnic chauraha to Transport Nagar) – 25 Km, Corridor 4 (Cantonment to Shaheed path)– 7 Km, Corridor 5 (Mahanagar to Shaheed path)– 12 Km, Corridor 6 (Engineering College to Medical College)– 7 Km, Corridor 7 (Vasantkunj to Telibagh)– 16 Km. Seven corridors have been identified in which corridor 2 from Bithauli crossing to Polytechnic chauraha is finalised for study area.

Availability of ROW

Availability of ROW on different junction of Study Area are as follows: Bithauli Crossing – 30 m, Engineering College Chauraha – 45 m, Kanchana Bihari Marg – 35 m, Sector -25, Indira Nagar – 35 m, Munshpulia – 40 m and Polytechnic Chauraha – 40 m as shown in Map 1. Passenger demand is above 6000 person per hour per direction. Study area fulfils all the three requirements which are required to run a BRTS, therefore BRTS is feasible in Lucknow city.

Based on survey and analysis factors affecting the BRT Route

Factors which affect the BRT Corridor are: feeder system [14], user satisfaction [15], ridership and land use (TOD). [16] It has been analysed that Feeder services are lacking in some inner parts of the corridor, so people use their private vehicles to commute, compared to other modes of transportation, buses have a low ridership. As per the table, various modes have been taken for survey, in which time taken by different modes and money spent on the trip from Polytechnic chauraha to Bithauli Crossing has been analysed. IPT – Changing 2 autos to reach from origin to destination results in delay to reach to their final destination. 2 and 4-wheeler modes of transportation are convenient, but not as affordable as public transportation. The Bus is affordable, but the time taken by this mode is longer and the frequency of buses is also low. The best option for any trip is BRTS, as it takes less time due to dedicated lane as compared to other public transport and is affordable too.

Proposal

There are five essential features that define BRTS in the study area. It includes: Dedicated Right of Way, Busway alignment, Platform level boarding, Off-board fare collection and Intersection treatments. These five essential aspect result in a faster trip for commuters and make traveling on transit more efficient and convenient therefore it is necessary to get the basics right. As per BRT Guidelines for Indian Cities IRC, 2017, average spacing between stations should be between 300 to 800 m is optimal for commuters. [17] Therefore, proposing 800 m distance between two stations of BRTS. As total length of corridor is 12 km, it consists of 15 stations. The slope of the ramp should be convenient for all commuters especially for the differently abled users. Commuters can purchase tickets in the fare collection area, which also has information displays about the system. At least 1.1 m by 1.5 m should be available for the ticket booth. [17] The boarding area serves as a waiting area for buses as well as circulation space for commuters arriving or departing the station.





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Availability of ROW on different junction of Study Area are as follows: Bithauli Crossing – 30 m, Engineering College Chauraha – 45 m, Kanchana Bihari Marg – 35 m, Sector -25, Indira Nagar – 35 m, Munshpulia – 40 m and Polytechnic Chauraha – 40 m A sensitive Local Area Plan (LAP) may provide incentives for TOD redevelopment. More Value Capture from development along transportation corridors is made possible by TOD. Along transit corridors, FSI could be increased.

CONCLUSION

Through primary survey it has been observed that Lucknow fulfils the basic requirements of BRTS. Therefore, BRTS is feasible in Lucknow City. As this corridor majorly covers residential areas, therefore, maximum trips originate from residential areas. Trips for all sections of society should be affordable and accessible, then only ridership will increase.

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Table.4: Purpose and modal choice for different trips Source: Author 2022

NO. OF COMMUTERS	PURPOSE OF TRIP	MODE OF TRAVEL
160	WORK	2W-96 commuters, 4W-34 commuters, Bus-6 commuters, Auto-24 commuters
18	EDUCATION	Bus-2 commuters, Auto-12 commuters, 2w-4 commuters
10	RECREATION	2w-4 commuters, 4w-5 commuters, Auto-1 commuters
4	SHOPPING	2w-1 commuters, Auto-3 commuters
8	HEALTH	4w-8 commuters
TOTAL-200 SAMPLE		

Table.5: Issues identified at junctions Source: Author 2022

Junctions	Issues Identified	
	Node Wise	Corridor Wise
Bhithauli Crossing	Traffic Congestion, Encroachment, No Bus Stop	Last Mile Connectivity, Feeder Services, No Footpath, Insufficient Parking
Engineering College Chauraha	Traffic Congestion	Last Mile Connectivity, Feeder Services
Kanchana Bihari Marg	Traffic Congestion, No Traffic Signals, Encroachment, No Bus Stop	No Footpath, Insufficient Parking
Sector-25, Indira Nagar	Traffic Congestion	Last Mile Connectivity, Feeder Services, No Footpath, Insufficient Parking
Munshipulia	Traffic Congestion, Encroachment	Insufficient Parking
Polytechnic	Traffic Congestion, Encroachment	No Footpath, Insufficient Parking

Table.6: Cost & Benefit Analysis Source: Author 2022

Parameter	IPT (Auto)	2-Wheeler	Car	Bus	BRTS
Time Taken (One Way)	33 min (2 autos)	20 min	25 min	30 min	24 min
Cost Per Km	Rs 2.25	Rs 2.5	Rs 6	Rs 1.25	Rs 2
Per Trip Cost (One Way)	Rs 27	Rs 30	Rs 67	Rs 15	Rs 24
Per Annum Cost for the Trip (260 days)	Rs 7020	Rs 7800	Rs 17,420	Rs 3900	Rs 6240



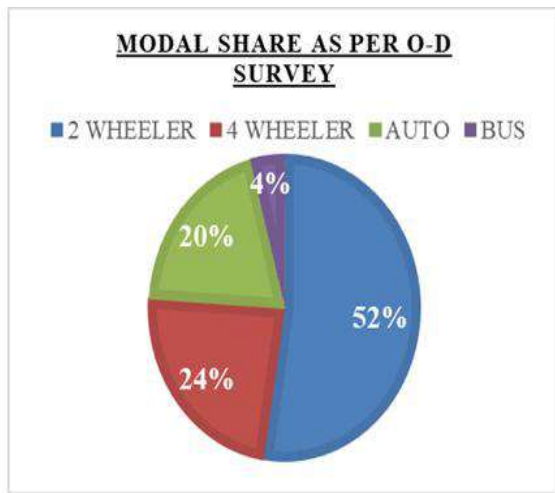
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Figure.1: Modal share as per O-D survey Source: Author 2022

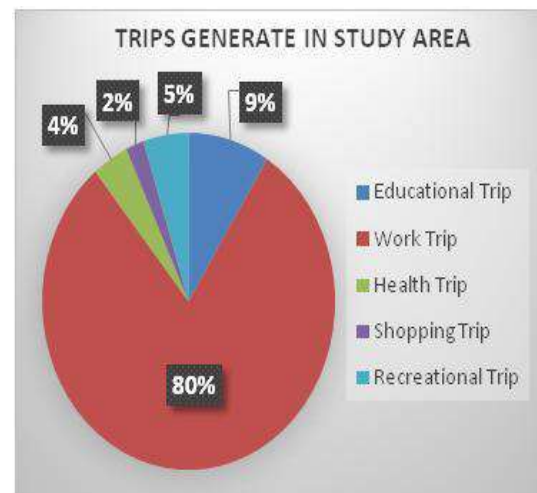


Figure.2: Different trips generate in study area Source: Author 2022

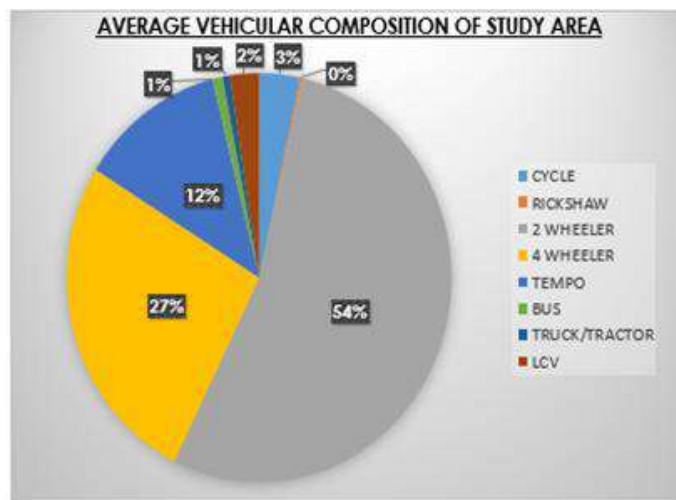


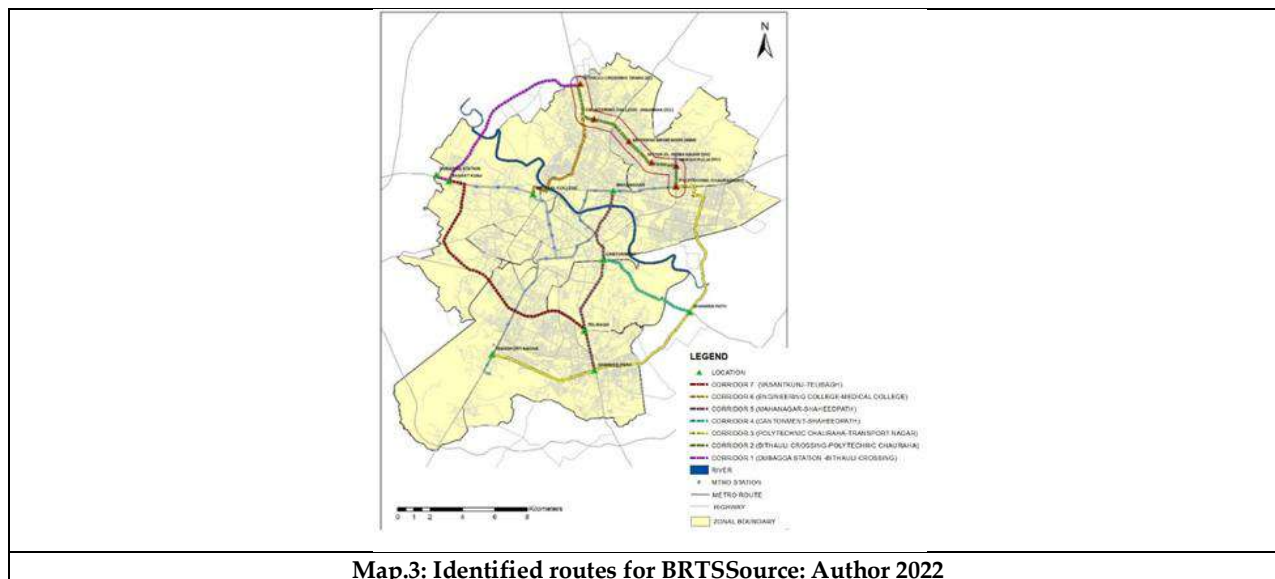
Figure.3: Average vehicular composition of study area Source: Author 2022



[illegible]



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Physico-Chemical Dynamics and Microplastic Contamination in Mysore's Kukkarahalli and Dalvoy Lakes

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ABSTRACT

This study focused on microplastic contamination and looked at seasonal changes in the water quality in Kukkarahalli and Dalvoy Lakes in Mysuru. Water samples were tested for microplastics, dissolved oxygen, conductivity, turbidity, pH, and nutrition levels. The findings indicated Dalvoy Lake had higher pollution and lower water quality than Kukkarahalli Lake, although seasonal variations did not affect sediment characteristics or water quality. Kukkarahalli Lake had a higher pH of 8.58 and a lower conductivity of 593.75. In the case of sediments, both lakes show a pH of less than 6.5, with higher conductivity in Kukkarahalli Lake. The microplastic content was 164 particles/m³ in Kukkarahalli and 212 particles/m³ in Dalvoy lake showing more polymers presence in Dalvoy lake. The findings highlight the importance of improved pollution control techniques and regular water quality monitoring to address water pollution and conservation.

Keywords: Water quality, Kukkarahalli Lake, Dalvoy Lake, Pollutants, Microplastic

INTRODUCTION

Life depends on water, which is crucial for ecosystems and human civilization. Water quality impacts industries, agriculture, the environment, and public health. To ensure that the water is pure and suitable for human consumption, a water quality examination is required [1]. Water's qualities are assessed by a scientific method to determine its condition and suitability for various applications. Water quality parameter analysis is extremely



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important since it affects the economy, public health, and the environment in a variety of ways. Water quality parameter analysis encompasses a broad variety of physical, chemical, and biological characteristics[2]. The physical attributes include things like temperature, turbidity, colour, and odour. The solubility of gases and biological activity in water is influenced by temperature. The amount of suspended particles in water is explained by its turbidity, but colour and odor might reveal the presence of organic or inorganic material pollution[3]. Examples of biological parameters include microbiological pollutants like *E. Coli* and coliforms, which may indicate fecal contamination and the potential presence of harmful organisms, and algal biomass, which may indicate nutrient pollution and the potential for hazardous algal blooms. Conductivity, pH, heavy metals, nutrients including phosphate and nitrogen, dissolved oxygen (DO), chemical oxygen demand (COD), and biochemical oxygen demand (BOD) are the final chemical parameters. The pH scale indicates how acidic or alkaline the water is, which is crucial for chemical reactions and aquatic life[4, 5]. Water quality analysis ensures safe drinking water. Pathogens, heavy metals, and chemicals can cause severe and mild medical conditions like malignancies, neurological abnormalities, and gastrointestinal illnesses. Frequent monitoring promotes public health and assists in the prevention of water-borne diseases[6,7]. According to the Central Pollution Control Board of India's standards for water quality monitoring, the metrics to be picked are primarily determined by how water is used in society[8]. The imbalanced entry and outflow of water may produce cultural eutrophication in these lakes. Excreta from humans and agricultural wastes, which are rich in fertilizers comprising nitrogen, phosphorous, and potassium phosphorus as the main factor restricting the growth of algae and eutrophication in lakes introduce nutrients into the water[9, 10]. The potentially toxic elements (PTEs), and polycyclic aromatic hydrocarbons (PAHs) are causing widespread contamination of aquatic environments. Sediments are the primary sink of PTEs in aquatic ecosystems, but their concentrations are not well characterized on a wide scale. Microplastics may absorb larger amounts of some elements than soil particles, making them a transport channel for pollutants. Microplastics have a large surface area and physicochemical properties similar to suspended particles with high concentrations of Fe and Mn oxides[11-13]. Heavy metal pollution in water sediments poses ecological and health hazards. However, there is currently a shortage of information about microplastic pollution. This study examines the link between microplastics and PTEs in sediments and water to enhance understanding of water and sediment quality. The purpose of this study is to provide comprehensive and continuing data on the water quality indicators specific to Dalvoy Lake and Kukkarahalli Lake.

MATERIALS AND METHODS

Study Area

Mysuru, 140 km from the City of Gardens, has a lot of large and small bodies of water. Kukkarahalli Lake, Lingambudi Lake, Devanoor Lake, Dalvoy Lake, and Karanji Lake are a few of the larger lakes[14, 15, 18]. The two lakes studied in this paper are shown in Figure 1. Kukkarahalli Lake, located at approximately 12.312° N and 76.628° E, has a catchment area of approximately 414 hectares and a lake area of approximately 58 hectares. The lake's water levels fluctuate with the seasons, reaching their highest points during the monsoon season and their lowest points during the dry season. The lake includes a variety of ducks, cormorants, egrets, herons, and pelicans and is home to approximately 180 known bird species[16, 17]. Dalvoy Lake is located on the outskirts of Mysore, to the southwest. Compared to Kukkarahalli Lake, it is located in a more rural location surrounded by small towns and agricultural areas. The lake has an area of around 215 acres. It is located at around 12.277° N and 76.637° E. The primary sources of water for Dalvoy Lake are rainfall, surface runoff, and input from nearby streams and agricultural areas. It was previously part of an irrigation system [14,17, 18].

Sampling

The two lakes under research, Kukkarahalli and Dalvoy, were sampled both upstream and downstream of each. Surface water and sediment samples were collected in triplicate from each site during the rainy (May-October) and dry (November-April) seasons. Specifically, between 10:00 a.m. and 12:00 p.m., two liters of bulk surface water samples were collected three times at each station, from 0-20 cm deep and 5-25 cm from the lake. The water samples were stored at 4 °C in plastic bottles until further testing. To collect sediment samples, the top 2 cm of silt from a 15



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cm by 15 cm quadrant at each site was removed with a stainless-steel trowel. To prevent contamination until further testing, approximately 2 kg of silt was collected and stored in aluminum foil.

Sample preparation

Samples were collected from many places at the surface and subsurface levels during various seasons (pre-monsoon, monsoon, and post-monsoon) using pre-cleaned polyethylene bottles and conventional techniques. The samples were kept in iceboxes and delivered to the lab within 24 hours for analysis. Physicochemical parameters were measured, including pH (using a digital pH meter), dissolved oxygen (DO) using the Winkler method, conductivity (using a conductivity meter), turbidity (via a Nephelometric Turbidity Meter), temperature (using a mercury thermometer), and nutrient levels (nitrates and phosphates) using spectrophotometry. Microplastic samples were collected concurrently, filtered via bulk sampling, and density-separated using a saturated sodium chloride (NaCl) solution. A stereomicroscope was used to identify the microplastics, which were then tested for polymer identification using Fourier Transform Infrared Spectroscopy. The ANOVA test was used to examine seasonal fluctuations and associations between water quality and microplastic contamination. All statistical analyses were performed using software such as SPSS, with strong quality control measures in place, such as equipment sterilization and triple measurements to ensure accuracy.

RESULTS AND DISCUSSION**Physico-chemical characteristics of water**

pH, Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Hardness as CaCO_3 , Total Alkalinity as CaCO_3 , Dissolved Oxygen, Biological Oxygen Demand (BOD), and Total Coliform comparison was shown in fig 2 and table 1.

pH

The Two-Way ANOVA results show a significant pH difference between the lakes ($F=15.280$, $p=0.001$). Specifically, Kukkarahalli Lake has a higher pH than Dalvoi Lake. However, there is no significant interaction between lake and season ($F=0.715$, $p=0.398$), indicating that seasonal fluctuations have no substantial effect on pH levels in either lake, as tabulated in Table 1.

Conductivity

For conductivity, the Two-Way ANOVA reveals a very significant difference between the lakes ($F=403.545$, $p=0.001$), with Dalvoi Lake having significantly greater conductivity levels than Kukkarahalli Lake. Furthermore, the interaction between the lake and the season is significant ($F=21.818$, $p=0.001$), demonstrating that the effect of the season on conductivity varies between lakes.

Total Suspended Solids (TSS)

The TSS results show a significant difference between the lakes ($F = 11.733$, $p = 0.001$), with Dalvoi Lake having higher TSS levels than Kukkarahalli. There is no significant interaction effect between lake and season ($F=0.733$, $p=0.396$), indicating that seasonal fluctuations have no significant impact on TSS levels across lakes.

3.1.4. Total Dissolved Solids (TDS)

The Two-Way ANOVA results show a significant difference in TDS between the lakes ($F=343.171$, $p=0.001$), with Dalvoi Lake having substantially greater TDS than Kukkarahalli Lake. The interaction of the lake and season is also significant ($F=18.537$, $p=0.001$), indicating that seasonal fluctuations affect TDS differently in the two lakes.

Hardness as CaCO_3

Water hardness varies significantly between the lakes ($F=182.323$, $p=0.001$), with Dalvoi Lake having higher hardness than Kukkarahalli Lake. Furthermore, there is a significant interaction effect between the lake and the season ($F=11.914$, $p=0.001$), demonstrating that the effect of the season on hardness varies between lakes.



**Ashashree and Raju****Total Alkalinity as CaCO_3**

The Two-Way ANOVA results reveal a significant difference in total alkalinity between the lakes ($F=99.091$, $p=0.001$), with Dalvoi Lake having a higher alkalinity. There is also a significant interaction between lake and season ($F=5.256$, $p=0.023$), indicating that seasonal fluctuations alter alkalinity in distinct ways in the two lakes.

Chlorides

For chlorides, the ANOVA shows a significant difference between the lakes ($F=182.548$, $p=0.001$), with Dalvoi Lake having greater chloride contents. The interaction impact between lake and season is also significant ($F=13.868$, $p=0.001$), indicating that seasonal fluctuations affect chloride levels differentially in lakes.

Dissolved Oxygen

Dissolved oxygen levels varied significantly between the lakes ($F=191.814$, $p=0.001$), with Dalvoi Lake having lower levels of dissolved oxygen than Kukkarahalli Lake. There is no significant interaction between lake and season ($F=0.290$, $p=0.593$), implying that seasonal fluctuations have no significant effect on dissolved oxygen levels in the two lakes.

Biological Oxygen Demand (BOD)

The two-way ANOVA results show a significant difference in BOD levels between the lakes ($F=180.255$, $p=0.001$), with Dalvoi Lake having higher BOD values than Kukkarahalli Lake. There is no significant interaction impact between lake and season ($F=0.236$, $p=0.630$), showing that seasonal fluctuations do not significantly affect BOD levels in lakes.

Total Coliform

The results for total coliforms demonstrate a significant difference between the lakes ($F=99.697$, $p=0.001$), with Dalvoi Lake having higher coliform counts. The interaction between the lake and season is not significant ($F=2.633$, $p=0.112$), indicating that seasonal fluctuations have no substantial effect on coliform levels in the two lakes.

Physico-chemical characteristics of sediments

pH, Conductivity, Total Nitrogen, Total Phosphate, Moisture Holding Capacity, Porosity, and Organic Carbon of lakes comparison shown in fig 3 and table 2.

pH

The Two-Way ANOVA results indicate a significant variation in sediment pH between the lakes ($F=3.912$, $p=0.050$). Dalvoi Lake has a somewhat higher pH than Kukkarahalli Lake. However, the interaction between lake and season is not significant ($F=0.707$, $p=0.405$), implying that seasonal variations have no meaningful effect on sediment pH in either lake.

Conductivity

Sediment conductivity varies significantly between the lakes ($F=3398.96$, $p=0.001$), with Kukkarahalli Lake having far higher conductivity than Dalvoi Lake. The interaction between lake and season is near to significance ($F=3.940$, $p=0.053$), indicating that, while the overall difference is substantial, the effect of seasonal fluctuations on conductivity is not visible.

Total Nitrogen

The findings indicate a significant difference in total nitrogen levels between the lakes ($F=1869.1$, $p=0.001$), with Kukkarahalli Lake having much higher levels of total nitrogen than Dalvoi Lake. There is no significant interaction effect between lake and season ($F=0.001$, $p=0.980$), indicating that seasonal variations have no substantial impact on total nitrogen levels in either lake's sediments.



**Ashashree and Raju****Total Phosphate**

Similarly, Kukkarahalli Lake has significantly higher total phosphate levels than Dalvoi Lake ($F = 1738.186$, $p < 0.001$). The interaction between lake and season is not significant ($F=0.097$, $p=0.760$), implying that seasonal variations have little effect on total phosphate levels in sediments.

Most Water Holding Capacity

There is a substantial difference in sediments' maximum water holding capacity between the lakes ($F=748.921$, $p=0.001$), with Dalvoi Lake having a larger capacity than Kukkarahalli Lake. Seasonal fluctuations have no significant effect on this metric ($F=0.054$, $p=0.817$), implying that both lakes' water-holding capacity remains constant throughout the year.

Porosity

The Two-Way ANOVA revealed a significant difference in sediment porosity between the lakes ($F=493.94$, $p=0.001$), with Dalvoi Lake having higher porosity than Kukkarahalli Lake. There is no significant interaction effect between lake and season ($F=0.057$, $p=0.812$), indicating that seasonal fluctuations do not significantly alter sediment porosity.

Organic Carbon

There is a substantial difference in organic carbon content between the lakes ($F=73.692$, $p=0.001$), with Kukkarahalli Lake having more organic carbon than Dalvoi Lake. The interaction between lake and season is not significant ($F=1.460$, $p=0.233$), implying that seasonal variations have no meaningful effect on organic carbon levels in sediments. Dalvoi Lake shows significantly higher conductivity, Total Dissolved Solids (TDS), hardness, alkalinity, chlorides, Biological Oxygen Demand (BOD), and total coliforms. These indicators reflect more severe pollution or higher environmental stress. From the results above, the mentioned parameters are significantly higher than the required specification and that of Kukkarahalli Lake. Commonly used indicators of the ionic content of water, conductivity, and TDS are frequently linked to the presence of dissolved salts and minerals. A range of synthetic polymers are released into the aquatic environment when larger plastic waste breaks down into microplastics. These polymers can absorb and leach chemical additives, heavy metals, and other contaminants into the water. Since some plastics, especially polyvinyl chloride (PVC), release chloride ions when they break down, the presence of chlorides in water can also be connected to microplastic contamination. Kukkarahalli Lake has higher sediment levels of pH, conductivity, total nitrogen, total phosphate, and organic carbon. Microplastics might alter the pH of sediments by interfering with several chemicals and contaminants. Dalvoi Lake sediments have higher water-holding capacity and porosity compared to Kukkarahalli Lake. Microplastics are ubiquitous in Dalvoi Lake sediments, which reason for increased porosity and capacity to store water when compared to Kukkarahalli Lake sediments. As microplastics are small in size and are in diverse shapes they affect the structure of sediments, altering their physical characteristics including porosity and water-retention capacity. According to studies, when microplastics are present the natural packing of mineral particles in sediments is disturbed, which results in a more loosely packed sediment structure with increased pore space¹⁹. Enhanced porosity becomes vital as it improves water flow through the sediment and has a direct impact on nutrient cycling and pollutant transport. The water-holding capacity of sediments is increased as microplastics can absorb the water immediately, particularly those with hydrophilic qualities or rough surfaces [20].

Microplastic content

According to statistics from the initial analysis of the microplastics, there were 164 particles/m³ in Kukkarahalli Lake and 212 particles/m³ in Dalvoi Lake. A graphical depiction of the abundance of various polymers is shown in Table 3. Fibers are the most prevalent form of microplastic found, followed by pieces. The high content of polymers detected in Dalvoi Lake means more pollution by polymers will enhance the low quality of water.





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CONCLUSIONS

The current study conducted a thorough assessment of the lake's water quality that further revealed the major influence of microplastics and pollution indicators, such as conductivity, total dissolved solids (TDS), hardness, alkalinity, chlorides, BOD, and total coliforms on the water quality of the two lakes. As per the data. The higher pH of 8.58 and 8.07 in Kukkrhalli Lake and Dalvoi Lake respectively is unsuitable for drinking. The conductivity is higher in the case of Dalvoi Lake of 1102.25 compared with Kukkrhalli Lake's conductivity of 595.25. The hardness and TDS of both lakes are lesser than the permissible limit when compared between the lake and the higher in Dalvoi lake. The sediment pH was less than 6.5 indicating the acidic nature of the sediments—the high polymer content results in decreased water quality in both lakes. Between Kukkrhalli and Dalvoi Lake the Dalvoi lake is contaminated with microplastics. The study's findings helped to conclude that strict pollution control measures and routine monitoring are necessary to ensure the sustainability of water resources.

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Conflict of interest

There is no conflict of interest among authors.

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Table 1. The mean Physicochemical parameter of the water sample in Kukkarahalli and Dalvoilakes along with the results of the two-way ANOVA test.

Lake	Season	PH		Conductivity		Total Suspended Solids		Total Dissolved Solids		Hardness as CaCO ₃		Total Alkalinity as CaCO ₃	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Kukkarahalli	Wet	8.58	0.31	595.25	60.96	38.33	5.77	392.5	48.07	193.33	29.01	154.33	35.75
	Dry	8.4	0.38	593.75	50.63	36.66	6.51	395.83	34.49	192	22.43	154.33	27.89
	Total	8.49	0.35	594.5	54.81	37.5	6.07	394.16	40.95	192.66	25.37	154.33	31.36
Dalvoi	Wet	8.07	0.32	1102.8	75.46	43.33	6.51	601.66	69.91	287	36.26	237.66	32.29
	Dry	8.07	0.43	912.25	91.19	45	7.97	731.66	44.68	350	38.83	287.33	50.67
	Total	8.07	0.37	1007.5	127.2	44.16	7.17	666.66	87.75	318.5	48.84	262.5	48.68
F-value (Lake)		F=15.280;p=.001		F=403.545;p=.001		F=11.733;p=.001		F=343.171;p=.001		F=182.323;p=.001		F=99.091;p=.001	
F-value (Lake*Season)		F=.715;p=.398		F=21.818;p=.001		F=.733;p=.396		F=18.537;p=.001		F=11.914;p=.001		F=5.256;p=.023	





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Table 2. The mean value of the Physicochemical parameters of sediments in Kukkarahalli and Dalvoi Lake along with the results of the two-way ANOVA test.

Lake	Season	PH		Conductivity		Total Nitrogen		Total Phosphate		Most water-holding capacity		Porosity		Organic Carbon	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Kukkarahalli	Wet	6.23	0.31	884.16	41.3	669.14	15.24	322.82	16.5	5.73	0.13	55.78	1.27	1.02	0.31
	Dry	6.05	0.38	905	27.24	670.3	17.65	316.48	26.71	5.74	0.15	55.88	1.47	0.84	0.38
	Total	6.14	0.35	894.58	35.84	669.72	16.14	319.65	21.95	5.73	0.13	55.83	1.34	0.93	0.35
Dalvoi	Wet	6.35	0.32	406.58	26.1	169.97	5.69	750.46	38.05	7.62	0.25	70	2.34	0.3	0.04
	Dry	6.35	0.43	393.75	17.92	170.95	7.98	750.46	51.87	7.66	0.35	70.4	3.28	0.3	0.04
	Total	6.35	0.37	400.16	22.86	170.46	6.79	750.46	44.49	7.64	0.3	70.2	2.79	0.3	0.04
F-value (Lake)		F= 3.912 ;p= .050		F= 3398.96;p= .001		F= 1869.1 ;p= .001		F= 1738.186;p= .001		F= 748.921 ;p= .001		F= 493.94;p= .001		F= 73.692 ;p= .001	
F-value (Lake*Season)		F= .707; p= .405		F= 3.940;p= .053		F= .001; p= .980		F= .097;p= .760		F= .054; p= .817		F= .057;p= .812		F= 1.460; p= .233	

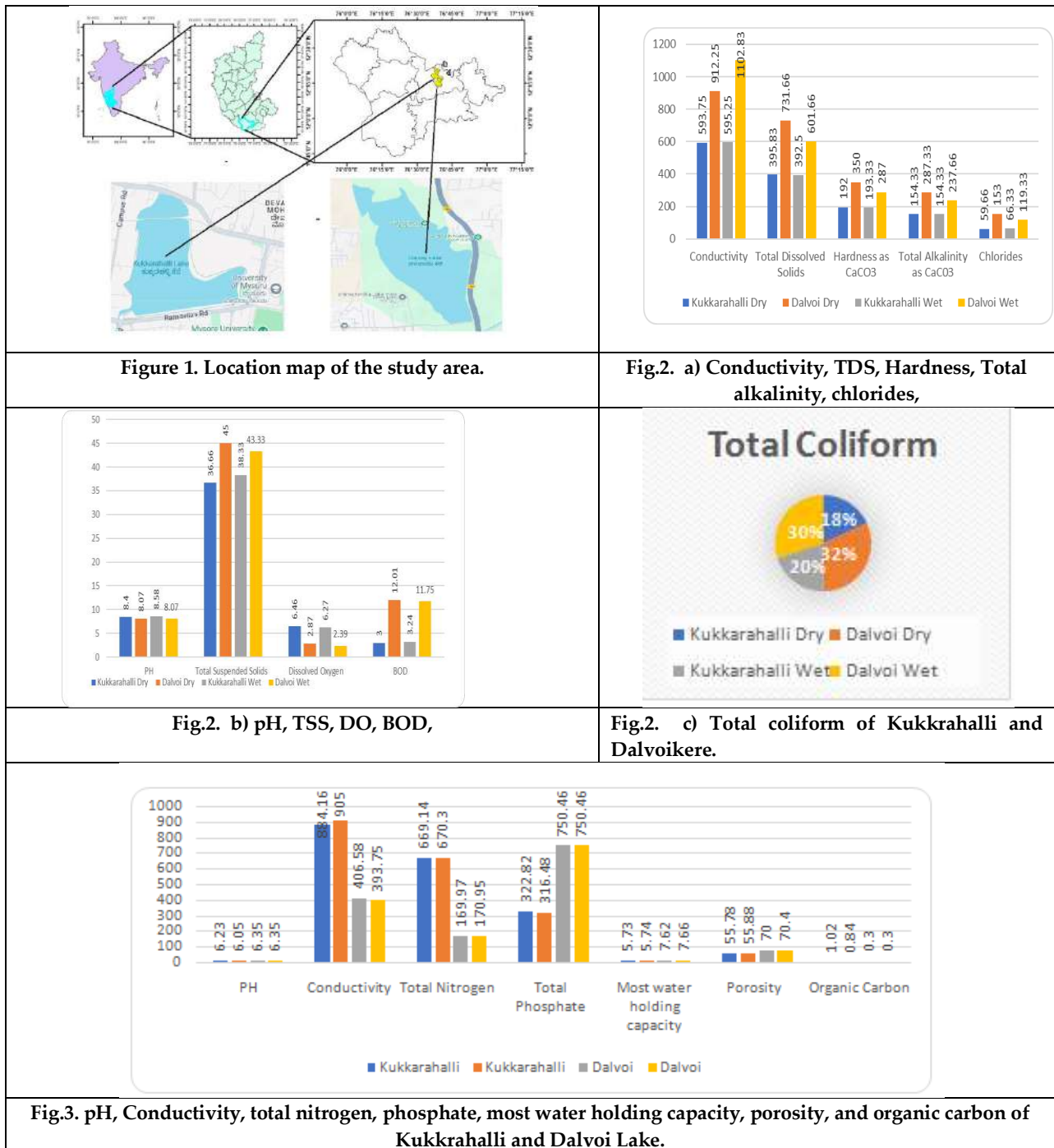
Table 3. Information indicating the nature and quantity of the polymer.

Kukkarahalli	Fibre	132
	Fragment	32
	Total	164
Dalvoi	Fibre	154
	Fragment	58
	Total	212





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Scanning Electron Microscopic Changes in the Fat Body of Adult Male *Sphaerodema rusticum* (Heteroptera : Belosmatidae) Treated with Chromium

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ABSTRACT

The present study is aimed to find out the scanning electron microscopic changes in the fat body of the adult male *Sphaerodema rusticum* treated with the median lethal concentration (LC₅₀, 14 ppm) of chromium for 48h. The present results revealed that characteristics SEM changes in the fat body of treated insect than control insect such as shrunken ruffled membrane with small pinocytotic pits. The disorganized cytoplasmic in origination indicates the occurrence of less amount of storage substance may probably be utilized for the insects to avoid the stress during the chromium intoxication.

Keywords: *Sphaerodema rusticum*, Fat body, SEM changes, Chromium, Ultra structure.

INTRODUCTION

Scanning electron microscopic study was used to surface observation and characterization of tissues. The scanning electron microscope (SEM) is an engineering instrument that has been shown to a useful investigative tool in surface modification. Scanning electron microscopy is an important tool in many morphology studies, that SEM shows



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surface structure (Song, Y *et al.*, 2013; Liu, C. 2008). The scanning and transmission electron microscopy (SEM and TEM, respective) are used to great effect to study their morphology and internal anatomy (Yan-Ru Zhang, 2020). However, during preparation of insect samples for electron microscopy (EM), the objectivity and authenticity of the observation site may be affected (Chen, X.F and Hu,M,Y, 2001).In general, SEM sample preparation of insects requires cleaning, tissue fixation, dehydration, metathesis, drying and sputter-coating (Zhou, W *et al.*, 2006).SEM studies were performed to probe the mechanism of action of the local isolates as compared to commercial and reference strains (Tanvi Sharma *et al.*, 2017). The assessment of pollution impact on aquatic ecosystems is usually based on both physical and chemical analysis of water quality and biomonitoring of living organisms. How were, the emphasis in evaluation of the environment pollution of surface water has been recently shifted to monitoring of bioindicator species (Rochfort *et al.*, 2000; Wright, J.F., 2000).The heavy use of chemicals has already caused grave damage to health and ecosystems (Ambika *et al.*, 2012). Among traditional used bio-indices, a majority are founded on taxonomic differentiation of aquatic invertebrates or multispecies assemblages' sensitivity in response to human-induced stressors (Kefford, B.J *et al.*, 2011). Also morphological (Lenat, D.R, 1993) or behavioural (Johnson, R.K *et al.*, 1993; Marques, M.J, 2003) changes in comprehensively studied species that are caused by modifications of environment quality may turn out to be as exploitable as traditional biotic indices (Tszyd el, M *et al.*, 2015). The using of individual taxons as one-species universal bioindicators is gaining more and more attention in assessment of aquatic pollution (Tszydel, Met *et al.*, 2015). Morphological abnormalities of bioindicator species offer another useful tool for pollution assessment, reflecting metal exposure conditions via element concentration in organism tissues (Vuori, K.M and Kukkonen, J, 1996). The fat body is the main storage and intermediary metabolism organ of insects and is responsible for the synthesis and supply of haemolymph substances. It consists of a mass of cells located underneath the epidermis and, in some insects, that the fat body also surrounds the digestive and reproductive organs reviewed by (Haunerland & Shirk 1995 and Roma *et al.*, 2010).

Fat body cells, known as trophocytes, are clustered together by a thin basal lamina that expands into the haemocoel and forms amorphous lobes or ribbons that increase the organ surface area, which in turn enhance the exchange of substances between the organ and the haemolymph (Martins & Pimenta 2008, Arrese & Soulages 2010). Insect fat body is considered as tissue equivalent to that of the liver in vertebrates (Sobotnik *et al.*, 2016; Liu *et al.*, 2009;Gullan&Cransto, 2014). It is also responsible for many activities such as amino acid, nitrogen, lipid and carbohydrate metabolism and protein sythesis (Liu *et al.*, 2009; Arrese & Soulages, 2010; Li *et al.*, 2019). The fat body is divided into two regions in many insects. These are peripheral (PF) fat body located below the integument and perivisceral (PV) fat body, observed around the digestive tract (Resh & Carde, 2003; Lipovsek & Novbak, 2016). It is very important to know the structure and contents of trophocytes in these insects throughout their development (TugbaZulfikaroglu *et al.*, 2023). Although trophocytes of have been determined in the species of *Blattodea* orders (Park *et al.*, 2013; Makki *et al.*, 2014). The fat body, which also expresses a number of malespecific proteins in addition to takeout, is a candidate for mediating the observed behavioural effect (Fujii S, and Amrein H. 2002). The fat body is a major secretory tissue in both larvae and adults. It secretes factors into the hemolymph, the fly's circulatory system (Lazareva AA, *et al.*, 2007). This revolution in preparing pesticides from plants has reduced the environmental problems; avoid the hazardous effects from chemical pesticides and save the whole universe from the pesticide pollution. The high biotic potential of insect makes the reproductive process a subject of importance in applied entomology. In recent years the dynamic aspects of insect reproduction has received more attention (Adiyodi and Adiyodi, 1974). Hence, the present study was undertaken to find out the morphology of Scanning microscopic changes in the fat body with special references to male reproductive process in the test insect, *Sphaerodemarasticum* when intoxicated with chromium.

MATERIALS AND METHODS

The insects collected from the local ponds and steams were maintained in plastic through at the laboratory temperature of $28 \pm 5^{\circ}\text{C}$ with a relative humidity of 80 ± 5 percent. The insects daily fed with mosquito larvae, pieces of earthworm and aquatic plants. The insects were survived well on these feeds. The troughs were cleaned properly



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on every alternative day by changing the water. The nymphal instars hatched out from the egg were transferred to another plastic trough and thus, a continuous culture was maintained.

Scanning electron microscopic study

The mortality was recorded for *Sphaerodemarusticum* at 48 hours of exposure of the chromium of various concentrations. The calculated LC 50 value was chromium for 48h. After the exposure period, the fat body of control and treated insects were dissected out and the fat body tissues were fixed in 2.5 Glutaraldehyde in 0.1 phosphate buffer at pH 7.4 for 24 h, then the samples were washed in 0.1 m phosphate buffer and dehydrated in removal of water, the tissues were mounted on metal stubs using conductive tape, coated with a thin layer of conductive material is deposited only for non-conducting samples and they were examined with Scanning electron microscope (JEOL-JSM-IT 200).

RESULT AND DISCUSSION

There are numerous studies on the structure, composition and function of fat body in insect species (TugbaZulfikaroglu *et al.*, 2023). Under SEM and light microscopy, trophocytes were observed to constitute the main cell population. Trophocyte inclusions represent fat, protein and sugar reserves used by insects to meet their energy demands during reproduction and diapause, to provide energy for the developing embryo and to provide energy for prolonged periods of light (Arrese & Soulages, 2010). Trophocytes are the basic cells in the fat body and store lipids, proteins and glycogens (Arrese & Soulages, 2010; Azeezet *et al.*, 2014; Lipovsek & Novak, 2016). The fat body of the control insect was found to be the occurrence of trophocyte with web like ruffled membrane had several pinocytotic pits and secretory granules. The cytoplasm of the trophocytes seems to be flattened sheet around the nuclei, which could be seen as prominent bulges near the centre of the cells. In some locations, these protuberances to be occurred in sub-peripheral regions, while the outer margin of the membrane was appeared as rope like structure (Figure 1 and 2). The invagination resembled like pinocytotic pits was seen inside. Minute blebs associated with cytoplasmic invagination were also seen along the margin of the membrane. Penetration of macrophages and phagocytosis on such trophocytes were visible. The apices of secretory cell seem to be revealed the smooth secretory granules beneath the apical plasma membrane. The trophocytes of treated insects showed remarkable changes in the scanning electron micrograph such as shrunken ruffled membrane with very small pinocytotic pits. The protuberances near the centre of the cells were found to be shrunken (Figure 3 and 4). The outer margin of the rope like structure is disintegrated. Minute blebs associated with cytoplasmic invaginations were found to be disorganized, indicates the less amount of storage substance probably be utilized for the insects to avoid then stress due to heavy metal chromium intoxication. In the present study, it has been observed that characteristic SEM changes in the treated insects than the control insects such as shrunken ruffled membrane with small pinocytotic pits. These changes may be attributed due to treatment with median lethal concentration of chromium on *Sphaerodemarusticum*.

These results are in consistent with the works of ultra-structural study on *Ranaesculenta* during starvation. Similar results were observed by Sumathi (2005) and Lousia (2010) for *Gryllotalpa Africana* and *O. varicornis* treated with the pesticide endosulfan and the zoopesticide, pygidial secretion, respectively. The secretory epithelial cell was covered with very thick rope like structure with basement membrane consists of less amount of secretion by these affected cells, when insects are intoxicated with the heavy metal chromium. Several SEM changes have been observed in the fat body of *Sphaerodemarusticum* when exposed to chromium for 48h. The following SEM changes were observed in the treated insects like shrunken tubule with thick myoepithelial cells, the rope like structure of the plasma membrane, which was observed to be highly pycnotic and disintegrated cubical epithelial cells. The muscular layer was also found to be thickened and highly pycnotic. The pinocytotic vesicles pits were found to be disintegrated with less organized microvilli. Underlying the multiple metabolic functions associated with the fat body, the structural pleomorphism of this major insect organ has received limited attention (reviewed in Haunerland & Shirk, 1995). Generally studies show that trophocytes contain an irregular-shaped nucleus with dense chromatin and cytoplasm with various vesicular structures, mitochondria, GER and Golgi body (Paes-de-Oliveira & Cruz-Landim, 2003; Roma





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et al., 2010). These SEM changes perhaps attributed to interaction with the chromium. In the present study, the heavy metal intoxication led to disturbance in the specific mode of secretion by these pseudostratified epithelial cells than the control insects. In treated insects, it has further been revealed that the secretory vesicle and granules with more vacuoles and pits were not observed in the control insects, suggested that the mechanism of secretion may become impaired in the treated insects. These changes might be disturbed the reproductive physiology of *Odontopusvaricornis*, similar results have been also reported by (Verma and Raji, 2000) and (Sumathi, 2002) exposed to dichlorvos and endosulfan for *Oreochromismossambicu*; *Gryllotalpa Africana*, respectively. (Jayakumar, 1988) has observed the same changes in the *O. varicornis* treated with dimethoate. Similarly, (Balakrishnan, 1990) has noticed several SEM changes in *Pherosphuslissoderus* treated with dimethoate, which are similar to the results of other workers namely (Nirmaladevi, 1990) for *Catacanthus incarnates* exposed to phosphomidon. (Rajathi, 2004) exposed to heavy metal mercury for *Sphaerodemarusticum*, (Rameshkumar, 2004) for *Laccotrephesruber* exposed to heavy metal zinc, *Odontopusvaricornis* with pygidial secretion (Lousia et al., 2010), and (Shoba, 2011) exposed to phytopesticidenimbecide for *Sphaerodemarusticum*, (Vivekananthan et al., 2011) *Mylabrisindica* for phytopesticide and *Odontopusvaricornis* exposed to phytopesticidenimbecidide (Ramesh kumar et al., 2014). In the present study, it has been observed that characteristic SEM changes in the treated insects comparatively more than control insects such as shrunken ruffled membrane with small pinocytotic pits. These changes might be disturbed the reproductive physiology of heavy metal chromium on the test insect, *Sphaerodemarusticum* that the control insect.

CONCLUSION

The median lethal concentration of heavy metal chromium caused remarkable changes in the fat body of *Sphaerodemarusticum* when it exceeds required concentration of chromium for regular biological functions. It reduces the potentiality of reproduction. It reveals that, the chromium is considered as an effective heavy metal, eco-friendly for sustainable in the aquatic environment.

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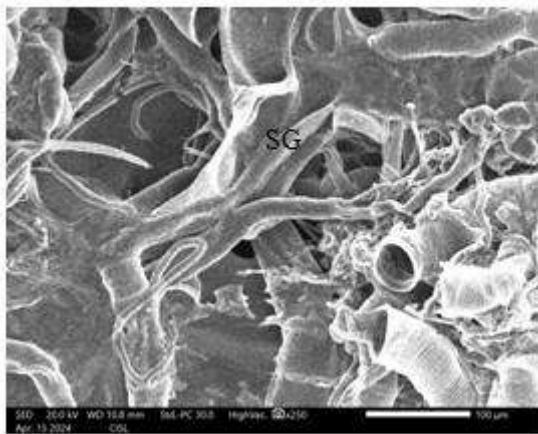
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SG -Secretory granules

Figure 1. Scanning electron micrograph showing the fat body of control insect x 250

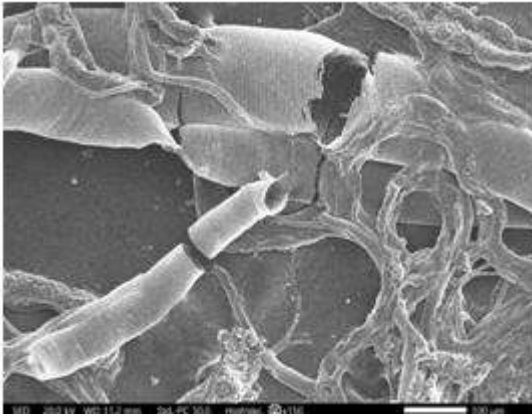


SV -Secretory vesicle

PP -Pinocytotic pits

Figure 2. Scanning electron micrograph showing the fat body of control insect x1000





DSV SPP

DCY-Disintegrated cytoplasm

DSV-Disintegrated secretory vesicles

SPP -Shrunken pinocytotic pits

Figure 3. Scanning electron micrograph showing the fat body of treated insect x 150

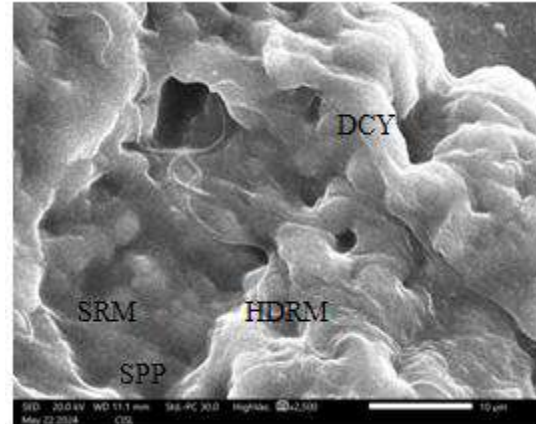


Figure 4. Scanning electron micrograph showing the fat body of treated insect x 2500

DCY-Disintegrated cytoplasm

SRM-Shrunken ruffled membrane

HDRM -Highly Disintegrated ruffled membrane

SPP -Shrunken pinocytotic pits





RESEARCH ARTICLE

Production and Characterization of Xanthan Gum from Agro-Industrial Waste

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ABSTRACT

Exopolysaccharides (EPSs) like Xanthan gum, produced by microorganisms like *Xanthomonas* species represent an industrially untapped market. These microorganisms can produce and excrete EPS in simple but costly production conditions. In the present study, xanthan production was investigated utilizing a local isolate of the *Xanthomonas* species in an effort to minimize the expense of the carbon source and maximize the overall yield of xanthan gum. Potential xanthan gum producers include isolates displaying yellow colonies, gram-negative rods, and mucoidal characteristics calcium Carbonate enriched media. These requirements were satisfied by two isolates obtained from diseased tomato leaves and lemon fruit. Bacterial isolates from diseased plant leaves and fruits were defined as *Xanthomonas* spp. based on their morphological and biochemical characteristics. The molecular analysis of the xanthan gum producing isolate (LI) revealed that it was *Xanthomonas oryzae*. An attempt was made to synthesize xanthan gum from cheaper carbon sources such as agro-industrial wastes (molasses, bagasse, and orange peels). Production conditions of xanthan gum and their relative viscosity by these bacterial isolates were optimized using yeast dextrose calcium carbonate medium containing agroindustrial carbon sources and various temperatures and rotations. The highest level of xanthan gum (62.5 g/l) with a relative viscosity of 1.05 was produced at 30 °C, pH 8.0, and 150 rpm using orange peels as a carbon source in an orbital shaker. Chilled isopropanol was used to recover the xanthan gum. FTIR spectral studies were also confirmed the successful recovery of Xanthan gum by detecting the chemical groups.

Keywords: Xanthan; *Xanthomonas oryzae*; Agro-industrial waste; Microbial exopolysaccharides; Polymers; FTIR spectra; lemon fruit; Relative viscosity



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INTRODUCTION

Biopolymers are polysaccharides formed by microorganisms, specifically yeasts, molds, and bacteria. Because these complex chain polysaccharides can form gels or viscous solutions in aqueous conditions, they are also known as gums. The importance and potential applications of gum use in industry are demonstrated by the widespread use of xanthan gum as a suspension-thickening and stabilizing agent, particularly in the food, cosmetic, pharmaceutical, and petrochemical sectors [1,2]. Xanthan's primary structure consists of repeating pentasaccharide units with a (1→4)-linked β -D-glucopyranosyl backbone, alternating D-glucosyl units, and terminal D-mannosyl units with pyruvic acid moiety and acetyl group substitutions[3]. The polymer's excellent structural and rheological characteristics render it suitable for use as a gelling and stabilizing agent across various industries [4]. Water - soluble hetero-exopolysaccharide xanthan is generated by the gram-negative bacterium *Xanthomonas campestris* [5]. *Xanthomonas campestris* is a plant pathogen responsible for causing diseases like bacterial leaf blight, black rot of crucifers, citrus canker disease, and others, which harm crops [4]. Xanthan, the microbial polysaccharide approved by the FDA and widely accepted commercially, is projected to grow from USD 0.62 billion in 2023 to USD 0.82 billion by 2030, exhibiting a compound annual growth rate of 4.73% during the forecast period (2023-2030). It's crucial to find a local strain of *Xanthomonas* species and enhance fermentation conditions for producing xanthan gum. FTIR analysis is vital for identifying chemical groups present in xanthan gum [4]. In the present study, we aimed to identify the most effective *Xanthomonas* species strain from nearby foliage and fruits such as lemons, and assess its ability to generate xanthan gum.

MATERIALS AND METHODS

Microorganisms and Media

Xanthomonas species was isolated from different leaves and fruits. Samples like mango, pepper, tomato and lemon showing black rot symptoms with varying lesion shapes were collected from fields. After collection stored at 4°C for further analysis. Symptomatic plant samples were washed, dried, and excised. The excised tissues underwent surface sterilization with 1% sodium hypochlorite followed by rinsing with sterile distilled water and 70% ethanol. Teased tissue segments were incubated on nutrient agar plates at 25-30°C for 3-5 days for further analysis. Samples were streaked onto nutrient agar plates and incubated at 28-30°C for 48 hours. Yellow-pigmented colonies were chosen for subsequent characterization. The suspected bacterial colonies were selected and streaked onto the surface of complex solid media such as YDC (Yeast Dextrose Calcium Carbonate) and YPGA (Yeast Peptone Glucose Agar) plates for 48 hours at 30°C, followed by storage at 4°C. Every 14 days, the culture is transferred to fresh medium to maintain strain viability. To assess culture viability, YDC agar slants are incubated at 25°C for 3 days. Selective isolates were subjected to morphological, and biochemical characterization for the preliminary characterization of isolates [4,6,7].

Inoculum and culture condition

The inoculums required for xanthan gum production were prepared by inoculating 10 ml of sterile yeast dextrose calcium carbonate broth with the culture of isolates. The tubes were incubated at room temperature for 24h [8].

Xanthan gum production

Experiments were carried out in 500 ml Erlenmeyer flasks with 100 ml of medium containing sterile Glucose broth (containing g/mL Glucose 6g, Yeast Extract 0.6g, H_2PO_4 0.4g, $MgSO_4 \cdot 7H_2O$ 0.02g) incubated in a rotatory shaking incubator at 28 to 30°C, 150 rpm under shaking condition for 10 days. In the gum production process, 10 ml of inoculum was combined with 90 ml of production medium in 500 ml Erlenmeyer flask. The flasks were placed on an orbital rotary shaker for fermentation. After 10 days, samples were collected and boiled in water bath at 10 to 15 min for cell lysis followed by centrifugation at 8000 rpm for 10 min for cell debris removal. The remaining supernatant was utilized for xanthan gum isolation. Three volumes of chilled isopropanol were added to the supernatant, causing



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the xanthan gum to precipitate and settle down. The precipitated gum was then dried in an oven at 50-60°C until a constant weight was achieved[9].

Relative viscosity measurement

In a Rheoviscometer 1% KCl and 0.1% (W/V) gum solution were used to measure viscosity [10].

Optimization studies for Xanthan gum and Biomass production

The optimization studies involve the maximum xanthan gum and biomass production using various agro-industrial wastes as carbon sources, different pH and temperature conditions.

Effect of carbon sources

The optimization studies for xanthan gum production involved various carbon sources such as orange peels, molasses, and bagasse. Isolates were incubated at 30°C for 10 days in sterile glucose broth supplemented with different carbon sources while maintaining other conditions constant [3,11,12].

Effect of pH

pH optimization experiments were conducted using sterile glucose broth with pH levels ranging from 6 to 9. Isolates were incubated at room temperature for 10 days. Thus, the effect of different pH on production of xanthan gum and biomass were determined by maintaining other conditions constant [13].

Effect of Temperature

Temperature optimization trials involved incubating isolates in sterile glucose broth at temperatures of 25°C, 30°C, 35°C, and 40°C for 10 days each by keeping other conditions constant [14].

FTIR analysis

The Nicolet iS10 FT-IR spectrometer was utilized to analyze the functional groups of polymers, while the Rheolab QC Bohlin rheometer was employed for assessing the rheological characteristics [4,15,16].

16s rRNA gene sequencing

After isolating DNA from a culture, the scientist observed a singular band of high-molecular-weight DNA on a 1.0% Agarose Gel. Following PCR amplification, they obtained a distinct single amplicon band, which underwent purification to eliminate impurities. Using the primer 1492R and a BDT v3.1 Cycle sequencing kit on an ABI 3730xl Genetic Analyzer, the purified PCR amplicon was sequenced. The resulting gene sequence underwent comparison with sequences in the NCBI GenBank database via BLAST, with the top ten matches selected based on their maximum identity scores and aligned using multiple alignment software programs.

RESULTS

Sample collection from infected plant parts

A significant commercial product, Xanthan gum is a microbial exopolysaccharide (EPS) generated by *Xanthomonas* sp. responsible for a number of plant diseases, including bacterial leaf, citrus canker disease and black rot of crucifers, which can harm crops. In order to isolate *Xanthomonas* spp. black rot diseased infected fruits and leaves grown in Kansali village, Surat, South Gujarat were collected and used for isolation of promising Xanthan producing bacterial isolates. Various infected plant parts were collected such as pepper leaf, Mango leaf, tomato fruit, lemon fruit to isolate expected *Xanthomonas* sp.

Isolation and purification of *Xanthomonas* species

Colonies of *Xanthomonas* can range from yellow to yellow-orange. This typical growth was obtained from infected tomato fruit and lemon fruit named as TI and LI. Selective media play crucial role by providing an environment that



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favors growth of specific microorganisms while inhibiting the growth of others. The yellow pigmented and mucoidal characteristics showing colonies were observed on YDCA (Yeast Dextrose Calcium Carbonate Agar) plate Fig. 1a. *Xanthomonas* species can also grow on YPGA (Yeast Extract Peptone Glycerol Agar) may produce creamy, opaque and slightly mucoid colonies in texture. Similar results produced shown in Fig. 1b. Thus, the growth of bacterial strains from genera that produce xanthan was permitted by both selective mediums.

Identification of causal organisms:**Morphology and Biochemical characterization**

The isolates obtained on selective media were further subjected to gram's reaction and morphological characteristic studies. Colonial characteristics were recorded from YDC agar plate. The colonies were yellow, round, convex with smooth textures. Both isolates were gram negative, short rods. Results of biochemical tests were recorded in table 1. Lemon isolate (LI) and tomato isolate (TI) were showing positive test for Indole, MR, VP, Citrate, H₂S production, Catalase, Urea, KOH, Ammonia and starch hydrolysis test. Whereas, negative biochemical test for gelatin, Urea and Indole for tomato isolate.

16s rRNA gene sequencing:

16s rRNA sequencing, which allows for the comparison of genetic sequences to known data bases to infer taxonomic relationships. In this study, we employ 16s rRNA sequencing to identify the unknown organism isolated from Lemon fruit (LI). Experimentation method includes DNA isolation followed by 16s rRNA gene amplification using PCR Fig. 2(A). Our data analysis revealed a 92.93% sequence match with *Xanthomonas oryzae* strain YNCX Fig. 2(B). Furthermore, phenotypic characterization of the unknown organisms demonstrated its ability to produce Xanthan gum, a polysaccharide with various industrial applications. Xanthan gum production is a hallmark trait of many *Xanthomonas* species, including *X. oryzae*.

Xanthan gum production and its recovery

The isolate was inoculated in sterile glucose broth incubated at room temperature under shaking condition for 10 days. Intensity of broth color was increased and changed to the bright yellow, which was primary indication of xanthan gum for fermentation. In order to recover xanthan gum, centrifugation and precipitation was done by ice cold Isopropanol (IPA) followed by drying at 45 °C in oven for 2-3 hours. The dry weight of product was recorded. Precipitates of xanthan gum was obtained from Lemon isolate (LI) and absent in Tomato isolate (TI). Fig. 3a and 3b depicted the xanthan gum precipitation and recovery respectively. Tomato isolate was further subjected to optimization study.

Optimization of Xanthan gum and cell biomass production**Effect of carbon sources**

Xanthan gum has been successfully produced from orange peels extracts, bagasse and molasses using lemon isolate. Fig. 4a suggest the maximum yield of xanthan gum (112.8 g/L) with the orange peel as carbon sources. One more observation was that cell dry weight was also higher in orange peels (17.66 g/L) containing media which suggest favorable carbon source for greater growth of organisms. Different concentration of orange peels (3%, 5%, 7% and 10%) were used. The maximum yield of xanthan gum (60.61 g/L) was attained in 10% concentration of orange peels (Fig. 4b). The fermentation using *Xanthomonas* species and orange peels as the carbon source was best combination for maximum xanthan production.

Effect of pH, Temperature and Rotation

To observe the effect of pH, media were adjusted to different pH, was 6.0 to 9.0. The study revealed that as pH increased from 6 to 8 the xanthan gum production also increased and decreased beyond pH 8. Thus, the optimum pH for xanthan production was 8 and maximum yield was found to be 61.3 g/L. The optimum pH for biomass production is 8 and maximum production is 6.6 g/L (Fig. 5a). The effect of temperature on xanthan production was studied for temperature ranges from 28°C, 30°C, 35°C, 37°C, 55°C. It was found that as temperature increased from 25°C to 30°C, the production of biomass and xanthan gum also increased but further increase in temperature lead to



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reduction in production of both biomass as well as xanthan gum. It is clear that the optimum temperature for biomass and xanthan gum production was 30°C and maximum production of biomass was found to be 6.45 g/L and the maximum xanthan gum production was 61.5 g/L (Fig. 5b). The effect of rotation on xanthan production was studied in the range of 110 rpm to 150 rpm. It was found that as rotation increased from 110 rpm to 150 rpm, the production of biomass and xanthan gum also increased. The optimum spindle speed for biomass and xanthan gum production was 150 rpm inferred from Fig. 5c. The maximum production of biomass was found to be 7.2 g/L and xanthan gum production was 62.5 g/L. Table 2 represents overall idea on effect of different parameters such as pH, Temperature, and carbon sources on xanthan gum, cell dry weight and relative viscosity.

Effects of Temperature and Rotation on Viscosity

The relationship between temperature and viscosity as well as rotation and viscosity could be established by plotting the appropriate curves using experimental data obtained. The higher the spindle speed (shear rate) the lower the viscosities of xanthan gum can be inferred from Fig. 6a and this behavior is typical of non-Newtonian fluids. There was also a variation of viscosity as a result of increasing temperature. Xanthan gum viscosity increased as temperature increased from the range of 20 °C to 37 °C but decreased at 55 °C can be inferred from Fig. 6b.

FTIR analysis

The FTIR spectrum was used for detection of different functional groups of xanthan gum such as hydroxyl, carboxyl, carbonyl, and acetal groups. The x-axis represents wavelength (cm⁻¹). FTIR spectrum of the commercial xanthan gum contains peaks typically appear in the regions associated with OH stretching vibrations (around 3000-3500 cm⁻¹), C-H stretching vibrations (around 2800-3000 cm⁻¹), and carbonyl (C=O) stretching vibration (around 1600-1800 cm⁻¹). Similar peaks observed in our study where gum produced from LI isolate of lemon plant contained i.e. carboxyl (2974 cm⁻¹), carbonyl (1640 cm⁻¹), acetal (1162 cm⁻¹), and hydroxyl groups (3358 cm⁻¹) as depicted in Table 3 and Fig. 7. These are very important groups formed during the production of xanthan gum from glucose. Xanthan gum with high acetal content was easily soluble in water, which was due to high hydrophilic properties of the produced xanthan.

DISCUSSION

A significant commercial product, Xanthan gum is a microbial exopolysaccharide (EPS) generated by *Xanthomonas campestris*. Plant pathogen *X. campestris* is responsible for a number of plant diseases, including bacterial leaf, citrus canker disease and black rot of crucifers, which can harm crops[4]. The isolation revealed the presence of yellow colonies, indicative of *Xanthomonas* species, prompting further confirmation. Two colonies, Gram-negative traits short rod and displayed a mucoid, convex form with a yellow pigmentation [17,18]. Cellular growth was assessed using a culture medium containing yeast, dextrose, and calcium carbonate (YDC) as it is suitable for this particular phytopathogenic bacteria [18-20]. The isolates obtained from selective media were subjected to Gram staining and colony-based morphological assessment, revealing gram-negative short rod-shaped cells with colonies exhibiting yellow, round, convex morphology and smooth textures on YDC agar plates. Many such literature studies gave rise to an idea to achieve the selective growth of xanthan producers on YDC agar. *Xanthomonas* species typically grow well on YDC agar as carbonates present in YDC agar enhance the growth of *Xanthomonas* by providing additional carbon source. It may produce small, circular, yellowish colonies with slightly raised edges. Similar results produced in our study as shown in Fig. 1a. *Xanthomonas* species can also grow on YPG agar and may produce creamy, opaque and slightly mucoid colonies in texture. Similar results produced shown in Fig. 1b. Both lemon isolate (LI) and tomato isolate (TI) demonstrated positive results in various biochemical tests indicative of Xanthan gum-producing microorganisms, such as Indole, MR, VP, Citrate, H₂S production, Catalase activity, Urea utilization, KOH string assay, Ammonia production, and starch hydrolysis. Results of morphological and biochemical studies aligning with findings reported in previous investigation by Naik *et al.* (2018) [6]. Furthermore, phenotypic characterization of the unknown organisms demonstrated its ability to produce Xanthan gum, a polysaccharide with various industrial applications. Xanthan gum production is a hallmark trait of many *Xanthomonas* species, including *X. oryzae*. Kim *et al.*, 2009 did mutational analysis of gum gene cluster required for xanthan biosynthesis in *X.*



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*oryzae*pv *oryzae* [21]. He found many ORFs consist of gumM, gumB gene with significant homology with the expected protein product of the gum gene cluster of *X. campestris*pv. *campestris*. This suggests the positive lead of xanthan gum production by *X. oryzae*. Various agro-wastes have been explored as economical substrates for xanthan gum production due to their abundance, low cost, and potential to serve as carbon source. Comparing the result of our study with Olanipekun *et al.*(2018), where *Xanthomonas campestris* yielded 8 mg/mL xanthan gum, our lemon isolate (*Xanthomonas oryzae*) showed a notably higher yield, suggesting its superior effectiveness in xanthan gum production³. This underscores the potential of orange peel as a promising carbon source, emphasizing the need for further optimization studies to enhance xanthan gum production. Such exploration aligns with the rising interest in eco-friendly and cost-effective industrial processes, emphasizing the importance of sustainable carbon sources. The influence of temperature on Xanthan gum production has been widely studied. The temperatures employed for Xanthangum production ranges from 28 °C to 55 °C[22]. Several studies on the synthesis of Xanthan, such as those by Gumus *et al.*, 2010; Kerdsup *et al.*, 2011, Psomas *et al.*, 2007, and Silva *et al.*, 2009, have shown that *Xanthomonas oryzae* flourishes best at neutral pH [13,14,23,24]. Because xanthan contains acid groups, during Xanthan formation the pH drops from neutral to values near to 5. These findings are supported by studies conducted by Borges *et al.* 2008 and Esgalhado *et al.* 1995[22,25].The viscosity and dissolution of xanthan gum is dependent on the temperature. The viscosity of the xanthan gum solution decreases by increasing temperature. With the increase of xanthan gum concentration, the viscosity increases with statistical significance as projected. Rottova *et al.*, 2009 and Khusherova *et al.*, 2024 have reported that viscosity has no correlation with the pH value because the viscosity values were not influenced by pH value [8,15]. The Xanthan gum generated in this investigation had an FT-IR spectra that matched the emission band pattern from the previous studies reported by Nayan *et al.*, 2019; Sinha *et al.*, 2012;Khusherova *et al.*, 2024 suggested the successful synthesis of xanthan gum[15,26,27].

CONCLUSION

Xanthomonas species can be isolated from the diseased lemon fruits had the potential to synthesize xanthan gum. *Xanthomonas oryzae* was discovered to be effective xanthan gum producer, producing 112.8 g/L xanthan gum for using orange peels as carbon source at 10% concentration after 10 days of incubation. This study focused on the optimization of xanthan gum production using various environmental and nutritional parameters. Incubation time of 10 days at 30°C temperature with pH 8 were observed to be optimal environmental conditions and orange peels was found to be optimal agro-waste for maximum production of xanthan gum. Using agro-waste in production of xanthan has high demand ensures a low-cost alternative with high productivity. Further, purification procedure is needed to obtain food grade xanthan.

Conflict of Interest

The authors declare that none of the work reported in this paper appears to have been influenced by any known competing financial interests or relationships

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Mansi Mulani *et al.*,**Table 1: Biochemical Characterization of Tomato and Lemon isolates**

Sr no.	Biochemical test	Tomato	Lemon
1	Indole	-	+
2	M-R	+	+
3	V-P	+	+
4	Starch hydrolysis	+	+
5	H ₂ S Production	+	+
6	Gelatin	-	-
7	Catalase	+	+
8	Urea	-	+
9	KOH	+	+
10	Ammonia	+	+
11	Fluorescent test	+	+
12	Citrate Utilizing Test	+	+
13	TSI	Slant=Red Butt=Yellow+G	Slant=Red Butt=Yellow+G

Table 2: Effects of pH, Temperature and Rotation on Xanthan gum, Relative viscosity and cell dry weight (Isolate-LI, Carbon source- orange peels (10% conc.))

	Optimization conditions	Xanthan gum concentration (g/L)	Cell dry weight (g/L)	Relative viscosity
pH	6 (30 °C, 150rpm)	30.6	4.0	1.58
	7 (30°C, 150rpm)	48.3	4.3	1.05
	8 (30°C,150rpm)	61.3	6.6	1.10
	9 (30°C,150rpm)	52.8	4.8	1.05
Temperature	28 °C (8 pH,150rpm)	45.5	4.8	1.05
	30 °C (8 pH,150rpm)	61.5	6.45	1.05
	35 °C (8 pH,150rpm)	51.3	4.12	1.02
	37 °C (8 pH,150rpm)	42.7	4.5	1.07
	55 °C (8 pH,150rpm)	26.3	2.3	1.06
Spindle speed (rpm)	110rpm (8 pH, 30°C)	35.46	5.2	1.10
	130rpm (8 pH, 30°C)	48.29	6.4	1.07
	150rpm (8 pH, 30°C)	62.5	7.2	1.05





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Table 3: FTIR spectral data for standard and sample product

Functional group	Hydroxyl	Carboxyl	Carbonyl	Acetal
Standard	3336	2120	1636	1160
Product	3358	2974	1640	1162

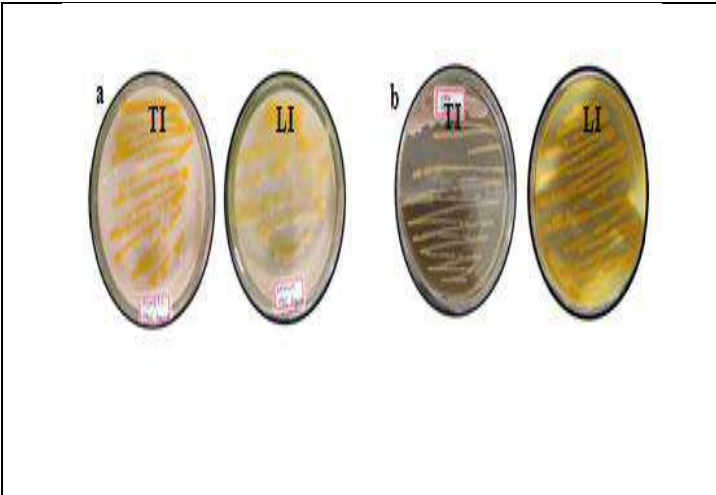


Fig.1: Isolation of *Xanthomonas* species using selective media. (a) YDC and (b) YPG agar

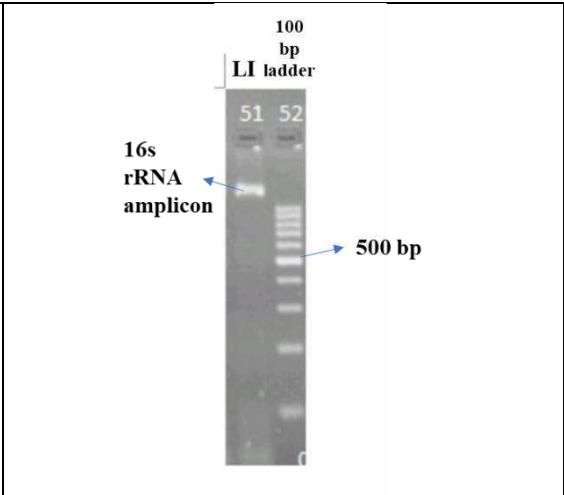


Fig 2(a): 16s rRNA gene amplification by PCR.

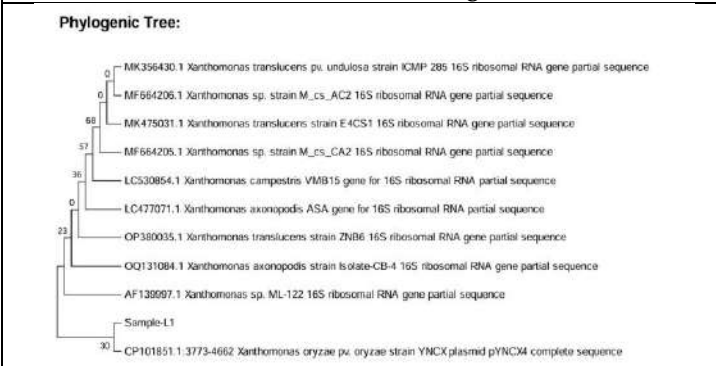


Fig. 2 (b): Neighbour-joining dendrogram depicting estimated phylogenetic relationships based on pairwise comparisons of partial 16s rRNA sequence of all the *Xanthomonas* strains examined. Sample LI represents *Xanthomonas oryzae* strain YNCX.

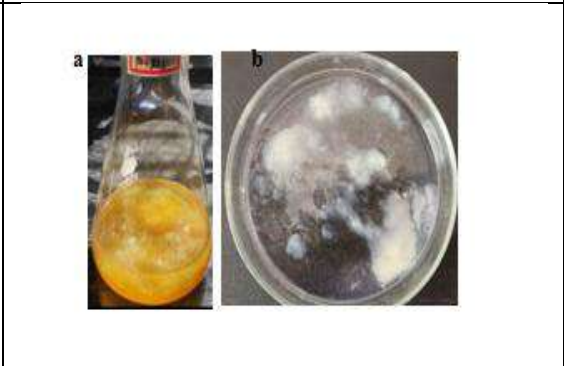


Fig. 3 Xanthan gum (A) Production, and (B) Recovery





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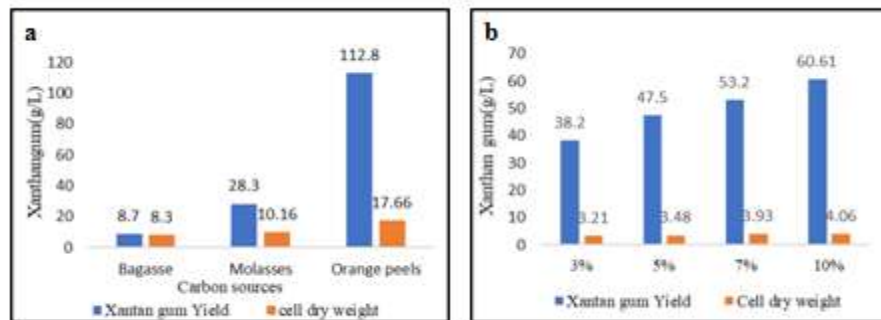


Fig. 4 (a) Effect of different carbon sources, (b) different concentrations of orange peels on xanthan gum and biomass production

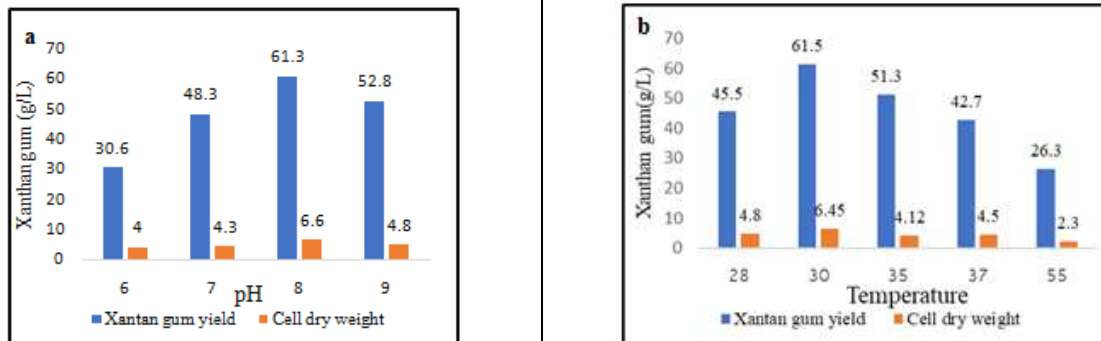


Fig. 5: Effect of (a) pH

Fig. 5: (b) Temperature

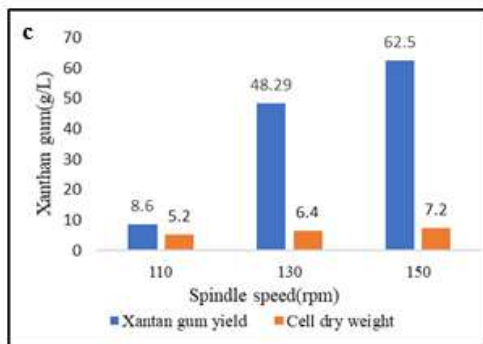


Fig. 5: (c) rotation (Spindle speed) on xanthan gum and biomass production

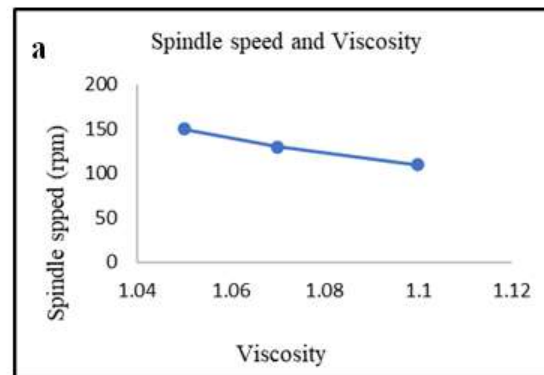
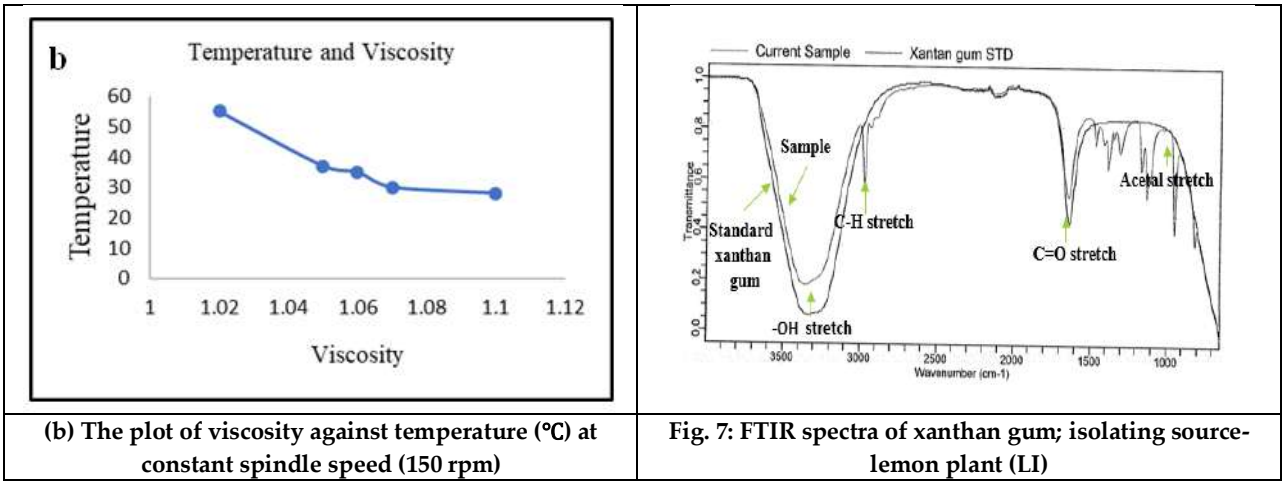


Fig. 6: Effect of Temperature and Rotation on Viscosity. (a) The plot of viscosity against spindle speed (rpm) at constant temperature (30 °C),





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RESEARCH ARTICLE

Systematic Significance of Anatomical Characterization on *Cleome* Species of the Family Cleomaceae

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ABSTRACT

The present study aims to explore the identification of taxa *Cleome* species by anatomical characteristics. The following species were selected to provide taxonomical evidence i.e *Cleome aspera* J. Koing ex DC., *C. felina* L. F., *C. viscosa* L., *C. gynandra* L. and *C. rutidosperma* DC. The anatomical observation on these plant materials has been made from different parts such as epidermis, trichomes, leaves, petiole, leaf venation, stem and root. The overall study showed significant anatomical variations from the sections of stem, root and petiole, whereas broader anatomical variations were identified from foliar abaxial epidermis and venation and areole characters of lamina. It was clear that certain structural characteristics such as epidermis and venation and areole were of significant importance in separation of these *Cleome* species. In this study, characters such as epidermal cells wall shape, number of epidermal cells, venation pattern and trichomes demonstrated a strong influence on the taxonomic identification of *Cleome* species.

Keywords: taxonomical evidence, *Cleome* species, anatomical observation, taxonomic identification.





INTRODUCTION

One of the oldest scientific fields, dating back thousands of years is plant taxonomy. It predates even the significant contributions made by Greek and Roman scholars such as Theophrastus, Pliny the Elder, and Dioscorides. The major navigations, the printing press, the establishment of botanical gardens, and the adoption of drying techniques to preserve plant specimens all contributed to the advancement of botanical taxonomy in the fifteenth and sixteenth centuries. Subsequent major steps in the history of plant taxonomy include the formulation of the principle of subordination of characters, the emergence of evolutionary theory, and the adoption of the dichotomous nomenclature binomial naming system (with Linnaeus playing a major role) and other universal rules for plant naming. These developments occurred concurrently with the growing body of morpho-anatomical data. Plant taxonomists have been looking for more accurate methods to comprehend the relationships between genera and families over the past fifty years. (Taia, 2005). More recently, the Hennig-initiated cladistics theory and the swift advancements in DNA technologies have made it possible to infer phylogenies and suggest real, genealogy-based classifications that are faithful to nature. Plant systematics, which aims to clarify plant variety, phylogeny, and evolution, has always been based on the comparative study of plant structure, morphology, and anatomy. Since the nineteenth century, anatomical data have been employed extensively as a taxonomic tool. Understanding the links between taxa at higher classification levels can be greatly aided by studying anatomy. As to Jones and Luchsinger 1987, several plant families possess numerous anatomical features that hold significant significance for their application at both the generic and sub-generic levels. In the exciting second part of the 20th century, new techniques and methodologies substantially aided systematics and structural research. (Endress *et al*, 2000). Using characteristics of anatomy, Auguste Mathiew, one of the first taxonomists, described the forest plants in *Florae Forestiere*. Later, in his seminal work "Systematische Anatomic der Dicotyledonen," another taxonomist named Solereder addressed the systematic significance of anatomical features in dicotyledons. Anatomical evidence is consistently helpful in many ways. For example, the taxonomic technique can be effectively applied to identify biological specimens that have been broken up into smaller pieces. (ii) When morphologies are not used to identify herbarium materials early on, studying anatomical demonstrations can be helpful. (iii) Anatomical information has shown to be extremely helpful in identifying linkages and evolutionary patterns across taxa at higher taxonomic levels and above the species level.

When figuring out the relationships between various genera, species, families, orders, and other taxonomic groupings, they are quite helpful. The evolutionary relationships have also been clarified in large part by the anatomical features. With eight species in the family Capparidaceae, Linnaeus (1753) initially described the genus *Cleome* L. Since then, numerous researchers (DE Candolle 1824, Bentham and Hooker 1862, Boissier 1867, Oliver 1868, Hooker 1875, Hedge and Lamond 1970, Jafri 1973) have studied this genus under the Capparidaceae family. *Cleome* and other related genera were previously included under the family Capparidaceae by floristic authors such as Hooker and Thomson (1872) and Cooke (1903). More recently, however, all of these taxa have been taxonomically split and placed into a different family, the Cleomaceae. Prior to DNA research (APG II system) revealing that the principal members of Cleomaceae are more closely related to Brassicaceae than Capparidaceae, many workers had treated this genus inside the family Capparidaceae (Stevens, 2001). With 180–200 species of herbaceous annual or perennial plants and shrubs that are extensively dispersed in tropical and subtropical regions, *Cleome* is the biggest genus in the Cleomaceae family. Approximately 150 species of *Cleome* have been identified in tropical locations, which are home to the majority of its variety (Raghavan, 1993). The genus *Cleome* was selected for the present anatomical character elucidation based on earlier descriptions, some unique morphological and floral characters in *Cleome* species may not be support to proper identification in all seasons. Such issues have been arising in particular characters such as leaf morphology, stem pubescence and glandular appearance, similar floral patterns and capsule type of fruits. In light of these facts the present study has explored based on anatomical aspects. The following species were selected to provide taxonomical evidence i.e *Cleome aspera* J. Koing ex DC., *C. felaina* L. F., *C. viscosa* L., *C. gynandra* L. and *C. rutidosperma* DC. The anatomical observation on these plant materials have been made from different parts such as epidermis, trichomes, leaves, petiole, leaf venation, stem and root. The taxonomic identification catalogue has prepared in order that the investigation on anatomical difference.



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MATERIALS AND METHODS

Collection of plant materials

Fresh plant specimens of *Cleome* species such as *C. aspera*, *C. monophylla*, *C. felina*, *C. viscosa*, *C. gynandra* and *C. rutidosperma* were collected from in and around the campus of N. G. M College in Pollachi. The collected plant materials were washed for removal of dirt and dust particles. Then the specimens were undergone for fixing process.

Preparation of FAA₅₀

The fixative solution made of formalin, acetic acid and ethyl alcohol (50%) were mixed in the ratio of 5 cc, 5 cc and 90 cc per 100 cc were added and stored accordingly (Toji Thomas, 2004).

Fixing process

Samples from the healthy parts *viz.* leaves, stem, petiole and roots were fixed in FAA₅₀ solution immediately after collection. After 24 hours, the fixed materials were stored in 50% ethanol for further studies.

Sectioning and slide preparation

Thin free hand sections of petiole, stem and root of selected plants were taken using razor blade and dehydrated with ethanol series (25%, 50%, 75%, 95% and absolute). The dehydrated sections were stained with 10% safranin and 0.1% fast green (Toji Thomas, 2004). The sections were placed on a clean slide and mounted in 50% glycerin and observe under the light microscope.

Epidermal studies

Healthy leaves of selected plants were collected and dipped in distilled water for 90 minutes to prevent them from drying. 3-4 leaves of each plant were kept in test tubes containing 30% of nitric acid and 70% of lactic acid in the ratio of 1:1. Then the test tubes were warmed using water bath till the leaves become transparent. Then the leaves were washed with distilled water for 2-3 times. The adaxial or abaxial surfaces of the leaf epidermis were separated very carefully, using pointed needle and hair brush. The separated epidermis portions were isolated and treated with a drop of lactic acid, to clear the surface and put on slide with coverslip. (Fazal *et al.*, 2018) The features of epidermal peels including the epidermal cell shape and stomatal types were observed. Stomatal index was calculated using the formula:

$$\text{Stomata Index (I)} = S / E + S \times 100$$

Where, S = Number of stomata and E = Number of ordinary epidermal cells plus the subsidiary cells in the same unit area (Metcalf, 1979).

Foliar vasculature study

Entire fresh leaves were submitted to 10 % sodium hydroxide solution and 20 % sodium hypochlorite solution in 2:1 ratio and stand for 2-3 days for transparency. The treated samples were stained with 0.01 % basic fuchsin stain for 24 hours using hot air oven at 60 °C. Then the stained leaf specimens were mounted in glycerin for microscopic evaluation (Valdne'a, 2014). The structural venation types were identification according to Hickey (1973).

Preparation of 0.01% of basic fuchsin

For 10 ml of stain, 0.001 gram of basic fuchsin was dissolved in 10 ml of 50% ethyl alcohol. The stain was in pinkish purple in color.





RESULT AND DISCUSSIONS

The anatomical studies on the stem, root, petiole and leaf blade of *Cleome* species i. e *Cleome aspera*, *C. felina*, *C. gynandra*, *C. rutidosperma* and *C. viscosa* shows that their own unique features. These studies were gave additional support for taxonomic identification. Their qualitative and quantitative anatomical features were under consideration in this study. These characteristic features of a species were compared with each other to develop a taxonomic key.

Stem anatomy

The stem of concerned plants were show a wide range of variations in following character; shape, trichomes, cortex organisation and medullary rays. The outline shape of the section was commonly in circular except *C. viscosa* and *C. rutidosperma* which were in wavy and angular respectively this was admit with the work of Okonwu (2017) on the anatomy of *C. rutidosperma*. The trichomes were present in all studied plant of *Cleome*. Glandular trichomes were present in *C. gynandra* and *C. viscosa*, while the nonglandular trichomes were occur in *C. aspera*, *C. felina* and *C. rutidosperma* (Fig. 1). In *C. rutidosperma* the nonglandular trichomes were spaciouly distributed which was agreed with Okonwu (2017). The cortex region was contains a different layers of cells as mentioned in Table 1. The cortex of *C. felina* and *C. viscosa* were made up of triple layers of cells. The results of *C. gynandra* and *C. viscosa* were accordance with Wael (2016). The interfascicular region was commonly incorporated by sclerenchymatous cells. According to Wael (2016) the interfascicular region of *C. viscosa* was homogeneous which was owed here also.

Root anatomy

The transverse section of roots were show a different characters based on the species as mentioned in the Table 2. It is considered all plant roots had secondary growth (Fig. 2). The major part of the root was reserved by xylem elements. There were ray parenchyma cells between these xylem elements. The layers number of these cells was minimum 3 in *C. aspera* and *C. rutidosperma* and maximum 15 in *C. felina*. In *C. gynandra* and *C. viscosa* he xylem reys were indistinguishable. The xylem elements were embedded mostly in sclerenchymatous or parenchymatous conjunctive tissue as mentioned in table 2. Due to the secondary thickening the pith was replaced by xylem elements. So mostly the pith was absent except *C. rutidosperma*. The cortical regions of *C. aspera* and *C. felina* showed that the intracellular starch grains are present. In *C. felina*, primary phloem elements also present in the cortical region.

Petiole anatomy

The petiole of the examined species of *Cleome* showed some variations in following characters, trichomes, hypodermis, bundle sheath and the number of lateral bundles as mentioned in Table 3. They were commonly had adaxial prominence with a deep furrow. The transverse section of petioles (Fig. 3) shows the prescence of trichomes in *C. felina*, *C. gynandra* and *C. viscosa*. In these *C. felina* had exceptionaly multicellular non glandular trichomes with small projection which was aid to identification. The hypodermis was commonly made up of chlorchymatous and collenchymatous cells as in Table 3. The chlorchymatous cells reserved part of hypodermis in all concerned plants. The vascular bundles were conjoint, collateral and open. They were embedded in parenchymatousgroud tissue. According to the classification of Hare (1942-1943) these are comes under the 'U' shaped petiole based on the petiole structure. The sclerenchymatous cells were surrounded the vascular bundle as a bundle sheath in *C. aspera* and *C. viscosa*. The vascular bundle which was possess straight below the furrow was considered as main bundle and other adjacent bundles were considered as lateral bundles. Here the number of the lateral bundles was minimum 2 in *C. aspera* and maximum 6 in *C. gynandra* and *C. viscosa*. Morvillez (1919), Watari (1934), Hare (1942-1943) and Howard (1962) were proposed different classification through their work based on different phenomina.

Epidermal study

The analysis of epidermal peelings from the lower surface of the leaves were manifested a wide range of contrasting characters in studied plants. These characters were found in the following phenomenon, anticlinal wall shape in frontal view, trichomes, length of the trichomes and stomatal index. The pavement cells were commonly undulate or wavy in *C. gynandra*, *C. rutidosperma* and *C. viscosa*. The non-glandular and glandular trichomes were distributed as



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mentioned in table 4 which had a similarity with stem. The length of those trichomes was varied from 0.5 mm to 4 mm (Table 4 & Fig. 4). *C. rutidosperma* and *C. viscosa* had very short glandular and non-glandular trichomes respectively. *C. gynandra* contains lengthy glandular trichomes were about upto 4 mm in height. According to many eminent authors from Metcalfe and Chalk (1979) and Watson (1963) to Attar *et al* (2019) had proven that stomatal structure and distribution has a strong implication on the taxonomic identification. Here all considered plants have anamocytic type of stomata. The distribution ratio of stomata was understood by calculating the stomatal index. In this work the stomatal index was minimum 13.6 in *Cleome rutidosperma* and maximum 33.79 in *Cleome felina*. The stomatal index and stomatal type of *C. gynandra* and *C. viscosa* were concealed with the anatomical work of Wael (2016). Whereas this results, was accordance with the work of Aleykutty and Inamdar (1978) on the ontogeny and structural study of stomata and trichomes of some capparidaceae members.

Foliar vasculature

The wide variation of venation in the studied species of *Cleome* was identified their venation pattern, marginal venation, areolation shape, areolation development and veinlets (Table 5 & Fig. 5). The result revealed that the commonest venation pattern in this study is the eucamptodromous in the species of *C. gynandra*, *C. rutidosperma* and *C. viscosa* whereas the *C. aspera* and *C. felina* were exceptionally identified as reticulodromous and cladodromous respectively. For the marginal venation also entirely different in *C. aspera* and *C. felina* (looped marginal venation) while other species were observed as fimbriate type of marginal venation. This is clearly help to differentiate for the identification of *C. aspera* and *C. felina* with use of venation evidence. Followed by the areolation shape is irregular in *C. gynandra* and *C. rutidosperma* whereas the other three species are identified as polygonal type of areolation shape (Figure 5). Also the similarities and differentiation of areolation development and veinlets are given in table 5. The major similarity among the species is the presence of eucamptodromous venation pattern. Recording the differentiation of leaf venation it is observed areolation shape, areolation development and veinlets. The particularly wide variation in leaf venation patterns of angiosperms has been classified by, for example, Ettingshausen von (1861), Melville (1976) and Hickey (1979). In the following, the widely used system of Hickey (1979) and its terminology is adopted. Whereas Ettingshausen von (1861) only considered leaf venation, the scheme of Hickey (1979) also uses other elements of leaf architecture in the classification process, such as leaf shape or the structure of the leaf margin.

CONCLUSION

Overall, the investigation revealed notable anatomical differences in the stem, root, and petiole sections, while more extensive anatomical differences were found in the foliar abaxial epidermis, venation, and areole characteristics of the lamina. It became evident that specific anatomical features, like the epidermis, venation, and areole, were crucial in helping to distinguish between various *Cleome* species. Characters including trichomes, venation pattern, number of epidermal cells, and wall shape of epidermal cells had a considerable influence on the taxonomic identification of *Cleome* species in this study. Ultimately, the study has demonstrated the value of using anatomical data to identify links between different taxa within a species. It is highly helpful in figuring out how different species relate to one another, and anatomical traits were crucial in clarifying evolutionary relationships.

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Table 1: Anatomical characters in T. S of stem

Characters	<i>C. aspera</i>	<i>C. felina</i>	<i>C. gynandra</i>	<i>C. rutidosperma</i>	<i>C. viscosa</i>
Shape	circular	circular	angular	angular	wavy
Trichomes	non glandular	nonglandular	glandular	nonglandular	glandular
Cortex	4- 5 layers of chlorenchyma	2-3 layers of collenchyma	2-3 layers of collenchyma	2-4 layers of chlorenchyma	2 layers of collenchyma
I. Outer					
II. Middle	-	3-5 layers of chlorenchyma	-	-	2-4 layers of chlorenchyma
III. inner	5-7 layers of parenchyma	4- 5 layers of parenchyma	4-5 layers of chlorenchyma	1-3 layers of parenchyma	2-4 layers of parenchyma
Inter fascicular region	parenchyma	parenchyma	sclerenchyma	heterogeneous	sclerenchyma

Table 2: Anatomical characters in T. S of root

S. No	Plant name	Xylem rays	Conjunctive tissue		Pith	Starch grains
			primary	secondary		
1.	<i>C. aspera</i>	3- 6 layers	sclerenchyma	parenchyma	-	+
2.	<i>C. felina</i>	10- 15 layers	sclerenchyma	parenchyma	-	+
3.	<i>C. gynandra</i>	Indistinguishable	parenchyma	sclerenchyma	-	-
4.	<i>C. rutidosperma</i>	3 layers	sclerenchyma		+	-
5.	<i>C. viscosa</i>	indistinguishable	sclerenchyma		-	-

Table 3: Anatomical characters in T. S of petiole

Plant name	Trichomes	Hypodermis	Bundles sheath	No. of lateral vascular bundles
<i>C. aspera</i>	-	chlorenchyma	+	2
<i>C. felina</i>	+	collenchyma and chlorenchyma	-	4-6





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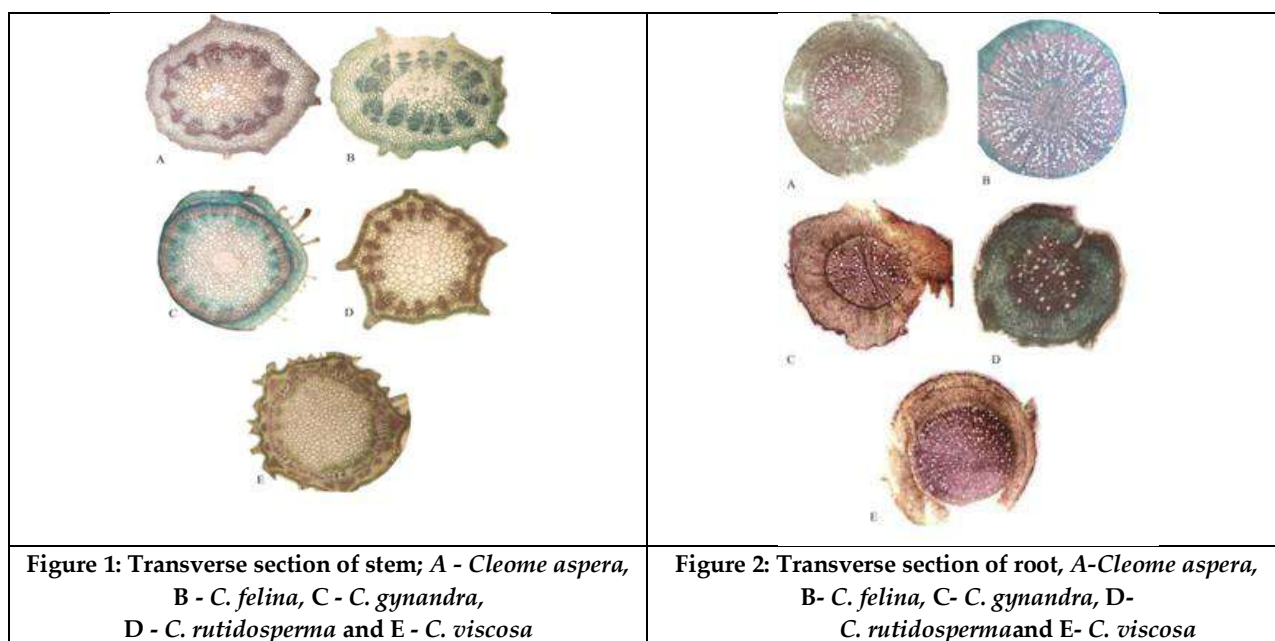
<i>C. gynandra</i>	+	collenchyma and chlorenchyma	-	6 (VB near to prominence was twined)
<i>C. rutidosperma</i>	-	chlorenchyma	-	4
<i>C. viscosa</i>	+	chlorenchyma	+	6

Table 4: Epidermal characteristics

S. No	Plant name	Anticlinal wall shape (frontal view)	Trichomes	Trichomes length (in mm)	No. of stomatal cells (average)	No. of epidermal cells (average)	Stomatal index
1.	<i>C. aspera</i>	polygonal	non glandular	0.8 – 1.3	35	133	20.8
2.	<i>C. felina</i>	polygonal	non glandular	1.5 – 2	49	96	33.79
3.	<i>C. gynandra</i>	undulate	glandular	2 – 4	20	113	15.03
4.	<i>C. rutidosperma</i>	undulate	non glandular	0.5 – 1	12	76	13.6
5.	<i>C. viscosa</i>	undulate	glandular	0.5 – 1.2	48	136	26.08

Table 5: venation and areole characters of lamina

Characters	<i>C. aspera</i>	<i>C. felina</i>	<i>C. gynandra</i>	<i>C. rutidosperma</i>	<i>C. viscosa</i>
Venation pattern	Reticulodromous	cladodromous	Eucamptodromous	Eucamptodromous	Eucamptodromous
Marginal venation	looped	looped	fimbriate	fimbriate	fimbriate
Areolation shape	polygonal	polygonal	irregular	irregular	polygonal
Areolation development	imperfect	lacking	incomplete	imperfect	incomplete
Veinlets	simple curved	once branched	branched once	simple curved	branched once





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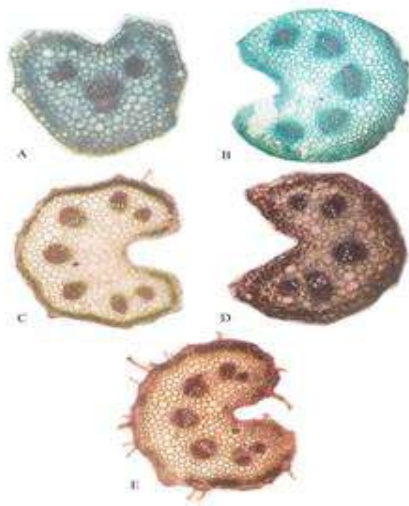


Figure 3: Trasverse section of petiole, A-*Cleome aspera*, B- *C. felaina*, C- *C. gynandra*, D- *C. rutidosperma* and E- *C. viscosa*

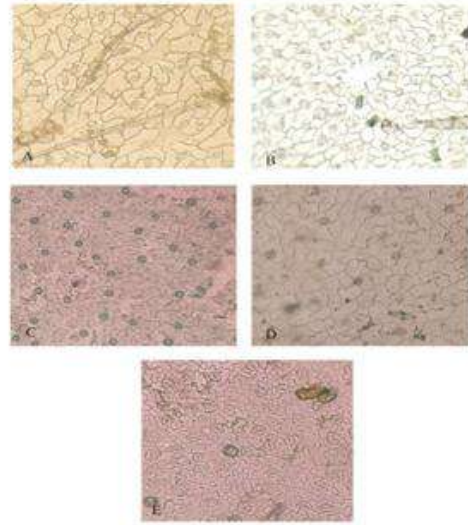


Figure 4 : Foliar abaxial epidermis, A-*Cleome aspera*, B- *C. felina*, C- *C. gynandra*, D- *C. rutidosperma* and E- *C. viscosa*

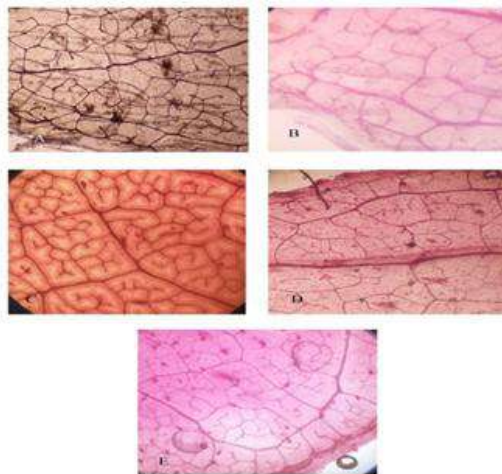


Figure 5: Foliar vasculature, A-*Cleome aspera*, B- *C. felina*, C- *C. gynandra*, D- *C. rutidosperma* and E- *C. viscosa*.





Preliminary Studies on Migratory Status and Seasonal Distribution of Birds of Majathal Wildlife Sanctuary, Himachal Pradesh, India

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ABSTRACT

The study conducted in Majathal Wildlife Sanctuary observed 82 bird species from 11 orders and 37 families, assessing their migratory status and seasonal distribution. During study 55 resident, 13 summer visitor, 7 winter visitor, 5 residents with altitudinal movement and 2 residents with local movement were observed. Seasonal variations in species abundance and diversity were noted, with spring hosting the highest Shannon diversity index and winter the lowest due to harsh conditions. Migration patterns were observed, with certain species arriving in winter from higher elevations experiencing snowfall. Some lowland species visited sanctuary during late spring and summer. This research offers significant insights into the avian ecology and seasonal dynamics of the sanctuary.

Keywords: Migratory status, Himalaya, Seasonal distribution, Bird diversity.

INTRODUCTION

Himalayas, a hotspot of global biodiversity and a repository of unique faunal and floral wealth [1], mark the southern boundary of the Palearctic in South Asia. Here, the transition from Palearctic temperate forests to the subtropical and tropical forests of Indomalaya fosters a diverse and abundant collection of plant and animal species [2]. The variations in elevation, rainfall patterns, and soil compositions, along with the elevated snow line, contributes to the presence of diverse biodiversity [3]. The vulnerable Himalayan landscapes face significant risks from natural hazards, intensifying concerns regarding the impacts of climate change [4-6]. These include landslides, floods, droughts and concerns about human health, biodiversity and agriculture [7]. Prins and Namgail[8] conducted





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a detailed study on bird migration across the Himalayas and assessed the impact of global change. Birds, being mobile creatures, are adapted to find environments that cater to their needs throughout different seasons [9-10]. This migration of birds involves regular and seasonal movement of populations from one geographic location to another [11]. In Himalayas or peninsular mountains, migration varies from short, local movements of just a few kilometres to extensive trans-Himalayan journeys covering several thousand kilometres [12]. Altitudinal migration involves birds moving horizontally and vertically across mountains. Some birds migrate from lowlands to Himalayan slopes in summer and return to lowlands in winter. Identification of impacts and timing of limiting factors for migratory birds is difficult due to the interconnectedness of their conditions throughout yearly cycle [13]. Understanding the arrival and breeding dates of birds is crucial for analysing the patterns in breeding timing amid climate change [14-16].

During both summer and winter seasons, the sanctuary is visited by birds known as summer and winter visitor, respectively. These birds are predominantly found during specific times of the year due to temperature and climatic variations. If they find favourable food sources in a particular area, they tend to stay there; otherwise, they migrate to more suitable areas. The studies on bird migratory status and seasonal variation [17-21] in Himachal Pradesh were conducted by various researchers. Pong Dam, key wetland in the area, attracting a considerable number of migratory birds from the plains of India and countries in Central Asia [22-23]. Likewise, Gobind reservoir stands out as a significant sanctuary within Himachal Pradesh due to its role in providing habitat for a diverse range of migratory bird species. There is scarce information regarding the diversity, migratory status and seasonal distribution of birds in the Majathal Wildlife Sanctuary. This study is the primary endeavour to document migratory patterns of birds in the sanctuary.

MATERIALS AND METHODS

Study area

The Majathal Wildlife Sanctuary is situated on the border of Solan and Shimla districts in Himachal Pradesh and present within latitude 31°15'00" N - 31°18'45" N and longitude 76°56'45" E - 77°02'18" E (Fig. 1). The altitude range of the sanctuary lies between 575 meters to 1975 meters above sea level and total area spanning over 30.86 sq. km [24]. The sanctuary exhibits cold winter and hot summer with temperature range from 1°C to 40°C. the rainfall varies from 17 mm in April to 348 mm in August. The flora of sanctuary includes Ban Oak Forest, Chir Pine forest, Deodar trees on higher elevations of the Chandi beat. Among the fauna present are Leopard (*Panthera pardus*), Black Bear (*Ursus thibetanus*), Himalayan Goral (*Naemorhedus goral*) and Barking deer (*Muntiacus muntjac*).

METHODOLOGY

The current study focuses on investigating the migratory status and abundance of the birds of Majathal Wildlife Sanctuary in different seasons throughout the year. The study was conducted from February, 2023 to January, 2024. The survey period was divided into four seasons based on climatic conditions. These four seasons were namely, Summer (May, June and July), Monsoon/Autumn (August, September and October) Winter (November, December and January) and Spring (February, March and April). The migratory status of birds was based on sighting in different seasons namely, Winter visitor (WV), Summer visitor (SV), Residential (R), Residential with Local Movement (R/LM) and Residential with Altitudinal Movement (R/AM). The birds survey involves either line transect and point counts [25-26] depending on the different habitats in the sanctuary. Bird identification followed the methods outlined [27-28] with nomenclature based on the guidelines provided by Manakadan and Pittie [29]. The diversity indices were used to calculate the species abundance and evenness present in the sanctuary. The data analyses performed by using PAST software. The following statistical diversity indices were used in the study:

Simpson's Index of Diversity (1-D)

$$= 1 - \sum n_i (n_i - 1) / N (N - 1)$$

Where, n_i = the total number of individuals of a particular species



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N = the total number of individuals of all species

Shannon Diversity Index H'

$$H' = -\sum p_i \ln p_i$$

Where, H' : Shannon Diversity Index

p_i : Relative abundance of each species = n_i/N

n_i : Number of individuals within a species

N: Total number of individuals in the sample

Species Evenness Index (E)

$$E_H = e^{H'/S}$$

Where, E_H = evenness index from Shannon diversity index

e = constant, that is base of natural logarithm

H = Shannon diversity index

S = Total number of species in a community

RESULTS AND DISCUSSION

The present study focuses on migratory status and seasonal distribution of various bird species found in Majathal wildlife sanctuary. The 82 species belonging to 11 orders and 37 families were observed in sanctuary (Table 2) and their migratory status were assessed. Analysis of conservation status revealed that one species falls under Vulnerable (VU), one species under Near Threatened (NT) and rest 80 species under Least Concern (LC) category. During study 55 resident, 13 summer visitor, 7 winter visitor, 5 residents with altitudinal movement and 2 residents with local movement were observed (Fig. 2a). During summer, monsoon/autumn, winter, and spring, the observed number of species were 62, 51, 42, and 66, respectively. Likewise, the number of individuals observed during these seasons were 382, 378, 282, and 456, respectively (Table 1). The highest number of species and individuals were found in spring season and lowest in winter season. The diversity indices provide measures of abundance and species evenness within each season. Simpson's index of diversity and Shannon diversity index both measure species diversity, with higher values indicating greater diversity. The Shannon index typically ranges between 1.5 and 3.5, with rarely going above 4.5. Values exceeding 3.0 suggest a stable habitat, while those below 1.0 signify an unbalanced ecosystem [30].

The species evenness index measures the uniformity of individuals among the species present, with values closer to 1 indicating more even distribution. The Shannon diversity index, ranging between 3 and 4, indicated that the overall diversity within the sanctuary was found to be good. During the spring season, the highest number of individuals was observed, coinciding with the highest Shannon diversity index value of 3.819 (Fig.2b). During spring, biodiversity reaches its peak due to several factors. Many species migrate from lower elevations as temperatures rise in those regions. Additionally, in the spring season, the blooming of numerous plant species provides nectar to birds and insects, leading to the flourishing of insectivorous and nectarivores bird populations. During early spring, the sighting of winter visitor birds was recorded, while in late spring, the appearance of summer visitors correlated with the observation of high Shannon index values. Monsoon/Autumn shows slightly lower diversity indices compared to Summer and Spring, but still maintains considerable biodiversity. The lowest Shannon diversity index was observed in the winter season, primarily due to harsh climatic conditions and limited food availability, resulting in fewer species being present. However, certain species, such as winter visitors, are found during this season as birds migrate to the sanctuary from higher elevations experiencing snowfall. The fire fronted serin (*Serinus pusillus*), wallcreeper (*Trichoderma muraria*), pink browed rose finch (*Caprodacus rodchroa*), white tailed nuthatch (*Sitta himalayaensis*), white capped bunting (*Emberizastewartii*), altai accentor (*Prunella himalayana*) and rock bunting (*Emberizacia*) was observed in the sanctuary during the winter season, as they migrate to the sanctuary from colder, higher regions. These birds typically remain in the sanctuary until mid-spring, around March, before returning to their higher elevation habitats. During the summer season, the Asian flycatcher and verditer flycatcher thrive





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abundantly due to the rich diversity and high numbers of insects. Some species found in low elevational areas or plains such as Eurasian collared dove (*Streptopeliadecaecto*), Oriental magpie robin (*Copsychussaularis*), Red vented Bulbul (*Pycnonotuscafer*), Indain robin (*Copsychusfulicatus*), White wagtail (*Motacilla alba*), Purple sunbird (*Cinnyris asiaticus*), Common myna (*Acridotheres tristis*), White throated fantail (*Rhipidura albicollis*) and Ashy prinia (*Prinia socialis*) come to the sanctuary during late spring and summer. The wallcreeper (*Trichoderma muraria*), prefers rocky surfaces, breeds within the sanctuary between December and February as noted by Saniga [31] in the Western Carpathians. In Tamhini, located in the northern Western Ghats, the study noted a high diversity of birds during the spring [32]. Similarly, a study conducted at Palampur Agricultural University showcased significant diversity, particularly from January to February [33].

CONCLUSION

The current work on the Diversity and Migratory status of birds in Majathal Wildlife Sanctuary has revealed that the overall bird diversity in the sanctuary is nearly good. Migratory patterns of birds changes in response to various climatic changes. The sanctuary hosts migratory species that inhabit the area during different seasons. Therefore, it's crucial to maintain undisturbed habitat and preserve the vegetation. Continuous monitoring of these resident and migratory birds is necessary to ensure their habitat conservation is effectively carried out.

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Table 1. Diversity indices for bird species observed across various seasons.

Seasons →	Summer	Monsoon or Autumn	Winter	Spring
Diversity Indices ↓				
Number of species	62	51	42	66
Number of individuals	382	378	282	456
Simpson's index of diversity (1-D)	0.9693	0.9629	0.9646	0.9713
Shannon diversity index (H')	3.782	3.555	3.515	3.819
Species evenness index	0.7083	0.6858	0.8002	0.6903

Table 2. Systematic index of avian fauna of Majathal Wildlife Sanctuary and their Migratory status

Sr No.	Scientific Name	Common Name	IUCN Status	Migratory Status
1	<i>Gyps himalayensis</i>	Himalayan Griffon Vulture	NT	R
2	<i>Falco tinnunculus</i>	Common kestrel	LC	R
3	<i>Upupa epops</i>	Eurasian Hoopoe	LC	R/LM
4	<i>Columba livia</i>	Rock Dove	LC	R
5	<i>Spilopelia chinensis</i>	Spotted Dove	LC	R
6	<i>Streptopeliadeocto</i>	Eurasian Collared Dove	LC	SV
7	<i>Meropsorientalis</i>	Asian Green Bee Eater	LC	R
8	<i>Cuculuscanorus</i>	Common Cuckoo	LC	R
9	<i>Eudynamysscolopaceus</i>	Asian Koel	LC	SV
10	<i>Glaucidium cuculoides</i>	Asian Barred Owlet	LC	R
11	<i>Dendrocoptesauriceps</i>	Brown-fronted Woodpecker	LC	R
12	<i>Picussquamatus</i>	Scaly-bellied Woodpecker	LC	R
13	<i>Picuscanus</i>	Grey-faced Woodpecker	LC	R
14	<i>Picumnusinnominatus</i>	Speckled Piculet	LC	R
15	<i>Megalaima virens</i>	Great Barbet	LC	R
16	<i>Psilopogon asiaticus</i>	Blue throated Barbet	LC	R
17	<i>Pssittaculacyanocephala</i>	Plum-headed Parakeet	LC	R
18	<i>Psittaculahimalayana</i>	Slaty-headed Parakeet	LC	R
19	<i>Lophuraleucomelanos</i>	Kaleej Pheasant	LC	R
20	<i>Gallus gallus</i>	Red Junglefowl	LC	R
21	<i>Pavo cristatus</i>	Indian Peafowl	LC	R
22	<i>Francolinusfrancolinus</i>	Black Francolin	LC	R
23	<i>Catreusvallichii</i>	Cheer Pheasant	VU	R
24	<i>Corvus macrorhynchos</i>	Large-billed Crow	LC	R
25	<i>Urocissaerythroryncha</i>	Red-billed Blue Magpie	LC	R



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26	<i>Urocissaflavirostris</i>	Yellow-billed Blue Magpie	LC	R
27	<i>Dendrocittaformosae</i>	Grey Treepie	LC	R
28	<i>Garrulus lanceolatus</i>	Black-headed Jay	LC	R
29	<i>Passer domesticus</i>	House Sparrow	LC	R
30	<i>Passer cinnamomeus</i>	Russet Sparrow	LC	R
31	<i>Aegithalos concinnus</i>	Black-throated Bushtit	LC	R
32	<i>Pycnonotusleucogenys</i>	Himalayan Bulbul	LC	R
33	<i>Hypsipetes leucocephalus</i>	Black Bulbul	LC	R
34	<i>Pycnonotuscafer</i>	Red-vented Bulbul	LC	R
35	<i>Serinus pusillus</i>	Fire-fronted Serin	LC	WV
36	<i>Carpodacus erythrinus</i>	Common Rosefinch	LC	R/AM
37	<i>Carpodacus rodochroa</i>	Pink browed rosefinch	LC	WV
38	<i>Phoenicuruscoeruleocephalus</i>	Blue-capped Redstart	LC	R
39	<i>Saxicola torquata</i>	Common Stonechat	LC	SV
40	<i>Myophonus caeruleus</i>	Blue Whistling-Thrush	LC	R
41	<i>Saxicola ferreus</i>	Grey Bush Chat	LC	R
42	<i>Eumyiasthalassimus</i>	Verditer Flycatcher	LC	SV
43	<i>Copsychusfulvicatus</i>	Indian Robin	LC	R
44	<i>Copsychussaularis</i>	Oriental Magpie Robin	LC	R
45	<i>Saxicola caprata</i>	Pied Bushchat	LC	R
46	<i>Muscicapa sibirica</i>	Dark-sided Flycatcher	LC	SV
47	<i>Monticola rufiventris</i>	Chestnut-bellied Rock Thrush	LC	R
48	<i>Argya striata</i>	Jungle Babbler	LC	R
49	<i>Trochalopteronlineatum</i>	Streaked Laughingthrush	LC	R
50	<i>Garrulaxleucolophus</i>	White-crested Laughingthrush	LC	SV
51	<i>Trichoderma muraria</i>	Wallcreeper	LC	WV
52	<i>Sitta himalayaensis</i>	White-tailed Nuthatch	LC	WV
53	<i>Phylloscopusxanthoschistos</i>	Grey-hooded Warbler	LC	R
54	<i>Phylloscopuschloronotus</i>	Lemon-rumped Warbler	LC	R/AM
55	<i>Phylloscopussindianus</i>	Mountain Chiffchaff	LC	R
56	<i>Motacilla alba</i>	White wagtail	LC	SV
57	<i>Anthusylvanus</i>	Upland Pipit	LC	R/AM
58	<i>Anthushodgsoni</i>	Olive-backed Pipit	LC	R
59	<i>Emberizastewartii</i>	White-capped Bunting	LC	WV
60	<i>Emberizacia</i>	Rock Bunting	LC	WV
61	<i>Emberizalathamii</i>	Crested Bunting	LC	SV
62	<i>Cecropisdaurica</i>	Red-rumped Swallow	LC	R
63	<i>Hirundo smithii</i>	Wire-tailed Swallow	LC	SV
64	<i>Dicrurusleucophalus</i>	Ashy Drongo	LC	R
65	<i>Dicrurushottentottus</i>	Hair-crested Drongo	LC	R/AM
66	<i>Cinnyris asiaticus</i>	Purple Sunbird	LC	SV
67	<i>Aethopyga siparaja</i>	Crimson Sunbird	LC	R/LM





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68	<i>Acridotheres tristis</i>	Common Myna	LC	R
69	<i>Rhipidura albicollis</i>	White-throated Fantail	LC	SV
70	<i>Prunella himalayana</i>	Altai Accentor	LC	WV
71	<i>Prunella strophlata</i>	Rufous-breasted Accentor	LC	R
72	<i>Certhia himalayana</i>	Bar-tailed Treecreeper	LC	R/AM
73	<i>Culicicapaceylonensis</i>	Grey-headed Canary Flycatcher	LC	SV
74	<i>Prinia crinigera</i>	Himalayan Prinia	LC	R
75	<i>Prinia socialis</i>	Ashy Prinia	LC	R
76	<i>Orthotomus sutorius</i>	Common Tailorbird	LC	R
77	<i>Lonchurapunctulata</i>	Scaly-breasted Munia	LC	R
78	<i>Parus major</i>	Himalayan-black Lored Tit	LC	R
79	<i>Parus cinereus</i>	Cinereous Tit	LC	R
80	<i>Heterophasia capistrata</i>	Rufous Sibia	LC	R
81	<i>Hemipus pictus</i>	Bar-winged Flycatcher Shrike	LC	R
82	<i>Terpsiphone paradisi</i>	Indian Paradise Flycatcher	LC	SV

Conservation Status: VU – Vulnerable, NT – Near Threatened, LC – Least Concern Residential Status: R – Resident, SV – Summer Visitor, WV – Winter Visitor, R/AM – Resident, show altitudinal movement, R/LM – Resident, show local movement.



Fig. 1. Map showing location of (a) Himachal Pradesh and Majathal Wildlife Sanctuary in India

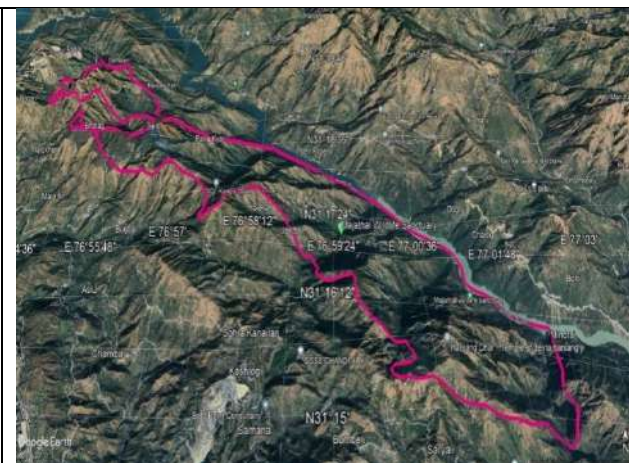


Fig. 1. (b) Outlined boundary of Majathal Wildlife Sanctuary. (Source: Google earth pro)





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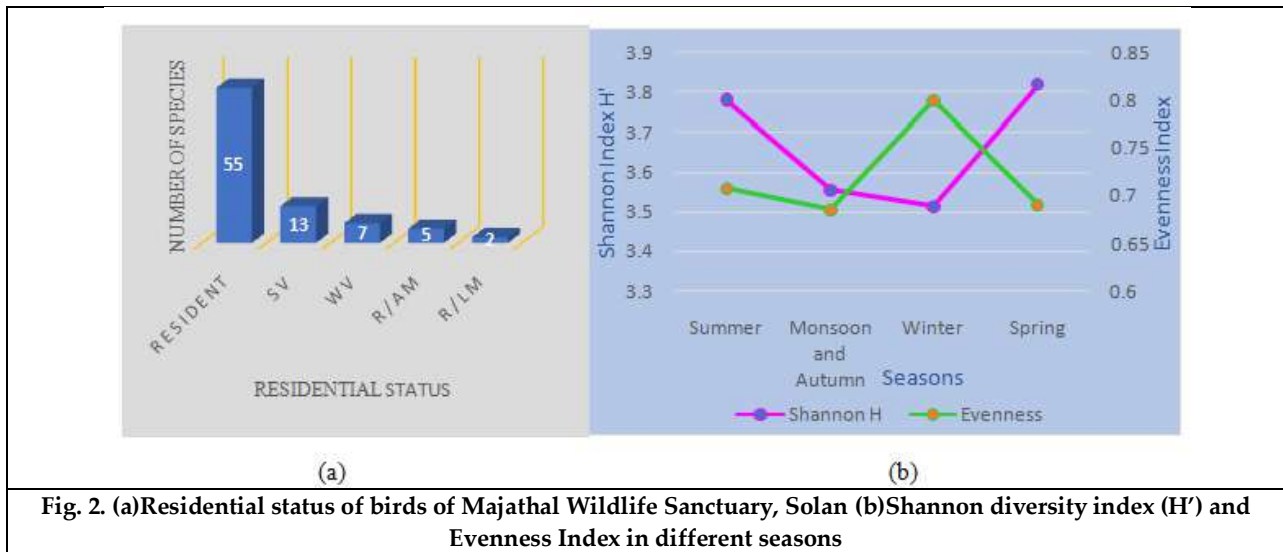


Fig. 2. (a)Residential status of birds of Majathal Wildlife Sanctuary, Solan (b)Shannon diversity index (H') and Evenness Index in different seasons





RESEARCH ARTICLE

A Pilot Study on the Correlation between Cheiloscopy Patterns and Ayurvedic Prakriti : A Randomised Open-Label Analysis

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ABSTRACT

Lumbar spondylosis, a common degenerative condition of the spine, is frequently observed in occupations involving prolonged driving, such as truck driving. This observational case series study aims to explore anatomical changes in lumbar vertebrae (Kati Kasheruka) among 30 truck drivers, with a focus on understanding their correlation with Kati Graha (lumbar spondylosis). Radiographic analysis was conducted to assess structural changes including osteophyte formation, disc space narrowing, and osteopenia at multiple levels of the lumbar spine, particularly L4-L5 and L5-S1. Participants were evaluated based on demographic characteristics, occupational history, and specific radiographic findings related to lumbar spondylosis. This study revealed a high prevalence of osteophytes and disc space reduction at the L4-L5 and L5-S1 levels among truck drivers, indicating significant degenerative changes in the lumbar spine. These findings underscore the impact of occupational demands, such as prolonged sitting and vibration exposure, on spinal health. This study provides compelling evidence linking occupational factors associated with truck driving to anatomical changes indicative of lumbar spondylosis. The observed degenerative alterations highlight the need for targeted interventions aimed at reducing risk factors and promoting spinal health among individuals engaged in professions characterized by prolonged driving. Future research should further explore preventive strategies and ergonomic interventions to mitigate the impact of occupational hazards on spinal health in high-risk populations.

Keywords: Lumbar spondylosis, Kati Kasheruka, Kati Graha, lumbar spondylosis





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INTRODUCTION

Ayurveda is the science of life which describes advantage and disadvantage, happiness and sorrow, good and bad, living being with proportions [1]. In Ayurveda, there is description of the whole-body including bones, muscles, organs etc [2]. Kati means waist, it is one of the anatomical terms used in Ayurveda [3], and Kasheruka means Merudanda (spinal column) [4]. The word Kati Graha originated from union of two words, Kati and Graha. The part of body which is covered with cloth[5]. Graha means to hold, it originated from dhatu GrahaUpadane which gives support. Kati Graha a condition which is characterized by Shoola & Sthabda due to vitiated Vata alone or along with Kapha which gets lodged in the Kati Pradesh. It is also called as Trika Graha and Prishta Graha [6]. Kati Graha explained as one of the Lakshana of Vata Vyadhi but, Bhavaprakasha & Gada Nighra explained separate diseases in Ayurveda classical text and Acharya Charaka while explaining 80 types of Vatajananatmajavikaras, he gives the description about Prustagraha. Kati Graha has mentioned indirectly in that [7] According to Shabdakalpdruma - Kati is the waist region where the dress is worn. [8]In Samhitas, Shroni or Kati is mentioned as a region rather than an organ. While numbering the Siraas, acharya Vagbhata has explained 32 Siras, among the 136 Siras present in the Antaradhi, are located in Shroni. Thus, to infer that Shroni is a region in the Antharadhi.[9'10] Kati is also mentioned as the seat for Vata dosha. Apana vata is mainly present in the Kati pradesha. [11] The intervertebral discs connect the upper and lower surfaces of the adjacent vertebral bodies, and extend from the axis vertebra to the sacrum.[12] Lumbar spondylosis can be described as all degenerative conditions affecting the discs, vertebral bodies. Spondylosis may be applied non-specifically to any and all degenerative conditions affecting the discs, vertebral bodies, or associated joints of the lumbar spine.[13] Chakrapani comments on this quoting that the height of Kati is not mentioned since another Sandhi is present between the heights of Uru (thigh) & Antharadhi (thorax & abdomen).[14] Acharya Sushruta says, the Pramana of Kati in males are 18 angulas in vistara (dimension) which is equal to the vistara of Urahpradesha of females.[15] Kati is also mentioned as the base for Vata dosha. Apana vata is mainly present in the Kati pradesha [16]. Radiating nerve pain caused by a prolapsed disc can also cause bowel and bladder incontinence[17]. Disc herniation's may be result from general wear and tear, such as constant sitting or bending, driving, or a sedentary lifestyle[18]. People over the age of 40 are at the highest risk of developing symptoms of lumbar spondylosis[19]. Upper limitation – could be taken as Nabhi, Lower limitation-could be taken as the Medhra & Mushka[20]. In Most of Samhitas it is mentioned that Kati as the sthana for VataDosha[21].

Acharya Sushruta has mentioned kati is the moolasthan for Medovaha srotas[22]. Kati is the region which is affected in many disorders such as, Katigraha in kshataksheenaand vaatajapradara, Katishula in Vaatodara, Vaatajarsha, Vaatajashula, Kati dourbalya in Darvikaravishavega, Katibhanga in 7th Vishavega. Similarly Kati shool also observed in like Gridhrasi and Grahani etc.[23-28] Back ache found in around 175.8 million days of limited motion each year in the United States. On some known time, 2.4 million Americans are difficult to move because of low back pain, along with 1.2 million on a constant basis. In the year of 2005, lower back ache, position as the number one reason of difficult to move in persons under the period of forty.[29] In the year of 1990, 400,000 industrial low back traumas lead to difficult to movement in the United States[30]. The effects of heavy physical activity are controversial, as is a purported relation to disk degeneration[31]. Professional drivers have been found to be at high risk for developing lumbar spondylosis due to prolonged sitting and vehicle vibration. As study has shown that whole body vibration to be factors which increase both the possibility and severity of spondylosis[32]. In addition to normal working hours, truck drivers may work overtime. This might lead to a long working week exceeding, in practice, the official working week[33]. Approximately 76% of computer professionals from India reported musculoskeletal discomfort in various epidemiological studies [34]. Lower back pain is also very common among workers whose work encompasses activities that involving long hours of sitting, standing and bending[35]. In the year 2005, lower back pain, position as the number one reason of difficult to move in persons under the period of forty[36]. Emphasize the energetic and reparative traits of the intervertebral disc, responding to variations in prolonged sitting, improper position, etc and influencing vertebral kinematics but a strong association remains between the presence of Osteophytes and others like disc space reduction, Osteopenia, spine deformities etc, even though isolated instances of one without the other occurs, in the absence of over symptoms. Thus, research



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substantiation setup in modern medicine bears out the classical Nidana to be causing initial degeneration[37]. Some conditions related to kati region is given below.

Kati Shula

The occurrence of pain in the lumbar region of the axial spine, specifically at sites of degenerative changes, is anticipated due to the presence of nociceptive pain generators in various anatomical structures, including the facet joints, intervertebral discs, sacroiliac joints, nerve root dura, and myofascial components within the axial spine[38].

Kati Sthambhata

The exacerbation and increase of Vata in its own site (Ashraya) negatively impacts Kapha and reduces its fluid component (Dravamsha). From a modern medical perspective, disc degeneration is associated with specific risk factors. Retrospective studies have identified Body Mass Index (BMI), back trauma, daily spine loading activities (such as twisting, lifting, bending, and sustained non-neutral postures), and whole-body vibration (e.g., vehicle driving) as contributors to the likelihood and severity of spondylosis[39].

Pada Harsha

defines as tingling sensation of the legs. As per the Chakrapani Teeka that due to the Prabhava of Vata the symptom may be formed/ arise. Whereas according to the Acharya Sushruta it is affected due to vitiated Vata and Kapha⁴⁰. As per Acharya Vaghbhatta opinion that the Vyana Vayu along with Kapha obstructs the lumen of the Sira and causes Pada Harsha. By dilatation of Sira this will get calmed[41].

Pada Shupthi

defines as numbness of the legs. In Charaka Samhita, Pada Shupthi has been mentioned as a symptom of Snayu Gata Vata whereas Sushruta Acharya has stated it as a condition of Rakta Avrita Vata. Acharya Vaghbhatta hold the view that vitiated Vyana Vayu produces Pada Shupthi⁴². In modern medical terms, compressive radiculopathy can lead to paresthesia, which manifests as hypoesthesia (reduced sensation) or hyperesthesia (increased sensitivity) in specific areas.

Pada Dhaurbhalya

At the chronic stage, due to pain cause the Pada Dhaurbhalya. As per Acharya Vaghbhatta mentioned aggravated Vyana Vayu as the one among the cause of Pada Dhaurbhalya[43].

Stinging pain

It is a symptom commonly seen in the condition in which the intervertebral disc degeneration in specifically lower back region or degenerative disk disease it is may be due to any nerve root pinch[44].

Burning Pain

It is a symptom commonly seen in low back pain in conditions when irritation of nerve root in the lower region of spine due to arthritis of spine's facet joints. Patient often explain that burning pain that can run through the gluteal muscle, to thigh, calf, and foot[45]. Due to excessive standing or sitting condition kinetic pressure comes on the Low back region[46]. The repetitive movements of flexion, Extension, Rotation, Lateral Flexion, either alone or in combination, that are often associated with resistance are the biomechanical movements that shows the highest prevalence of low back pain[47].

AIM AND OBJECTIVES

- Investigate the impact of driving on the lower back (Kati Kasheruka) of truck drivers, focusing on how it contributes to lumbar spondylosis.
- Analyze the connection between anatomical changes observed in lumbar spondylosis and related back ailments described in Ayurvedic texts.



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- Conduct a comparative review of Kati Kashheruka (lumbar vertebrae) and Kati Graha (lower back conditions) in Ayurveda and modern science.

MATERIALS AND METHODS

- An observational study observes participants without manipulating any variables.

STUDY DESIGN

Selection: Thirty diagnosed cases of Kati Graha (lumbar spondylosis) were recruited from the Outpatient Department of Parul Ayurved Hospital.

Study Approach: A two-pronged approach was adopted for this research:

1. **Conceptual Study:** This involved a comprehensive literature review. Relevant resources were gathered from:
 - Ayurvedic texts
 - Previous research works on the topic
 - Modern medical textbooks
 - National and international medical journals
 - Online resources (carefully selected and evaluated)
2. **Clinical Study:** The details of the clinical study design was be outlined in the following section.

INCLUSION CRITERIA

- Diagnosed Lumbar Spondylosis: Participants must have a confirmed clinical diagnosis of lumbar spondylosis.
- Age Range: The age range targeted was 40-50 years old.
- Driving Experience: Drivers needed to have a minimum of 10 years of experience behind the wheel.
- Work Schedule: Participants' typical daily driving hours should fall within the range of 6 to 8 hours.

EXCLUSION CRITERIA

- Surgical history of lumbar region.
- Accidental history of lumbar region with fracture of lumbar vertebrae.
- Inter vertebral disc prolapsed of lumbar vertebra
- Other vehicle drivers

DURATION- 90 days

CRITERIA FOR ASSESSMENT

This study incorporated both subjective and objective parameters to assess the participants' condition:

A. Subjective Parameters

These parameters rely on self-reported experiences of the participants:

- Kati Shula: Pain in the lower back
- Kati Sthambhata: Stiffness in the lower back
- Pada Shupthi: Numbness in the legs
- Pada Harsha: Radiating pain in the legs
- Pada Daurbalya: Weakness in the legs
- Range of Movement: Assessed flexibility of the lumbar spine
- SLR Test (Straight Leg Raise): Evaluates hamstring tightness and potential nerve impingement
- Lasègue's Test: Another test for nerve impingement in the lower back



**Riya Joy et al.,****B. Objective Parameters:****These parameters involve quantifiable measurements:**

X-Ray (LS-Spine) AP & Lateral Views: Images of the lumbar spine from front-to-back (AP) and side (Lateral) views to assess structural changes

Assessment Criteria

The assessment compared the subjective symptoms reported by the participants with the objective findings from the X-Ray examinations. This combined approach aimed to create a comprehensive picture of the participants' condition.

Statistical Design

Since this is an observational study, the data collected was analyzed using descriptive statistics. This involve summarizing the data using measures like frequency tables, means, and medians to understand the characteristics of the participants' symptoms and X-Ray findings.

OBSERVATIONS AND RESULTS**According to addiction**

26 (86.7%) subjects were addicted to Smoke. 25 (83.33%) were addicted to tobacco chewing followed by 22 (73.33 %) were addicted to Tea/ coffee. 20 (66.66 %) were addicted to alcohol.

Observations on Lakshana**DISCUSSION**

- Discussion on Addictions: The study found a high prevalence of smoking (86.7%) and tobacco use (83.3%) among the truck drivers with Kati Graha (lumbar spondylosis). Existing research suggests nicotine in cigarettes may be a culprit, potentially causing disc herniation through coughing or by harming disc health through impaired blood flow and nutrient deficiencies. While tea/coffee consumption (73.3%) wasn't directly linked to Kati Graha, it might contribute to dehydration, another potential risk factor. Dehydration due to the drivers' work schedules could hinder nutrient exchange in the spine, further promoting disc problems.
- Discussion on Range of movement: Repetitive biomechanical movements such as flexion, extension, rotation, and lateral flexion, either individually or in combination, particularly when performed against resistance, exhibit the highest prevalence of lumbar spondylosis.
- Discussion on radiological study: In radiography, the lumbar AP view reveals the morphology, alignment, and symmetry of the spinal column, including the spinous and transverse processes, pedicles, facets, and lamina. Lumbarization of S1 and sacralization of L5 are also evident. The lateral view highlights osteophytes, disc space reduction, osteopenia, and vertebral slippage. The oblique view provides a clear visualization of the facet joints and pars interarticularis. The intervertebral disc exhibits dynamic and reparative properties, responding to variations such as prolonged sitting, improper posture, and excess weight, which influence vertebral kinematics. There is a strong correlation between the presence of osteophytes and other conditions like disc space reduction, osteopenia, and spinal deformities, although isolated occurrences of these conditions without accompanying symptoms do exist. Modern medical research supports classical Nidana (causative factors) as contributors to initial degeneration.
- Discussion on Examination: The examination of the back is completed by evaluating straight leg raising (SLR), muscle strength, sensation, and reflex activity in the legs. Pain and limitation during SLR are indicative of a prolapsed intervertebral disc, particularly when there is irritation or compression of a sciatic nerve root. Tight hamstring muscles can produce similar symptoms; however, if severe pain occurs, it is advisable to lower the leg just below the SLR limit and observe if gentle passive dorsiflexion of the foot reproduces the pain. If uncertainty remains, dorsiflexion of the foot at the SLR limit should be performed. This maneuver further stretches the sciatic nerve, increasing pain, without affecting the hamstrings. This is known as Lasegue's Test.





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CONCLUSION

Lumbar spondylosis, with its clinical manifestations, pathogenesis, and complications, can be effectively correlated with Kati Graha as described in Gada Nighraha. In this study, the majority of subjects were between 46-50 years old, with 16-20 years of work experience and an average of 8 hours of daily activity. The findings revealed significant disc space reduction primarily at L4-L5, followed by L5-S1. Structural changes, such as osteophyte formation and osteopenia, were predominantly observed at L4, L5, and S1. This study conclusively demonstrates that truck drivers are particularly susceptible to structural changes in these vertebrae. Comprehensive efforts were made to thoroughly review the literature and correlate the anatomical changes associated with lumbar spondylosis with the conditions described in Ayurvedic classics. This study highlights the occupational risks and underscores the importance of preventive measures and early intervention for individuals in similar professions.

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Table 1 Distribution of subjects according to Lakshana

Lakshana	No of patients	Total n %
Katishula	30	100 %
Kati sthambhata	30	100 %
Pada shupthi	21	70 %
Padaharsha	4	13.33 %
Padadhaurbhalya	10	33.33 %

Table 2: Distribution of subjects according to Flexion

Flexion (Degree)	No of Pt.	Percentage
30-40	23	76.66
41-50	5	16.66
51-60	2	6.66

Table 3: Distribution of subjects according to Extension

Extension (Degree)	No of Pt.	Percentage
10-20	23	76.66
21-30	5	16.66
31-40	2	6.66

Table 4: Distribution of subjects according to Lateral Flexion

Lat. Flexion(Degree)	No of Pt.	Percentage
10-20	27	90
21-25	3	10

Table 5: Distribution of subjects according to Rotation

Rotation (Degree)	No of Pt.	Percentage
10-20	27	90
21-25	3	10





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Table 6: Distribution of subjects according to SLR Test

SLR Test	No of patents	Total n %
Less than 30 Degree	17	53.33 %
30-60 Degree	9	33.33 %
Above 60 Degree	4	13.33 %

Table 7: Distribution of subjects according to Lassegue's Test

Lassegue's Test	No of patents	Total n %
Positive	24	86.7 %
Negative	6	13.33 %

Table 8: Distribution of subjects according to Involvement of Vertebrae

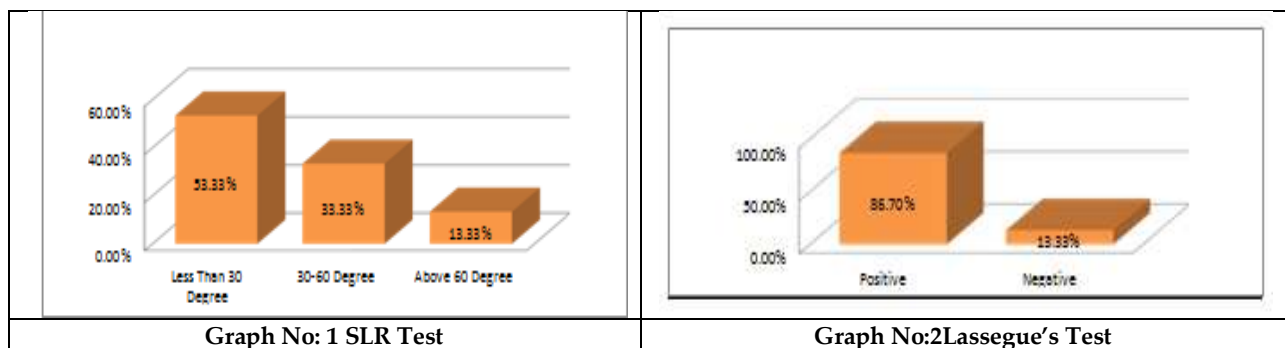
Involvement of Vertebrae	No of patients	Total n %
L1	1 (Out of 30)	3.33 %
L2	3 (Out of 30)	10 %
L3	9 (Out of 30)	30 %
L4	27 (Out of 30)	90 %
L5	26 (Out of 30)	86.7 %
S1	17 (Out of 30)	56.7 %

Table 9: Distribution of subjects according to Structural Changes: Intervertebral Disc Space

Intervertebral Disc Space	No of patients	Total n %
L1-L2	1	3.33 %
L2-L3	1	3.33 %
L3-L4	3	10 %
L4-L5	5	16.66 %
L5-S1	17	56.67 %

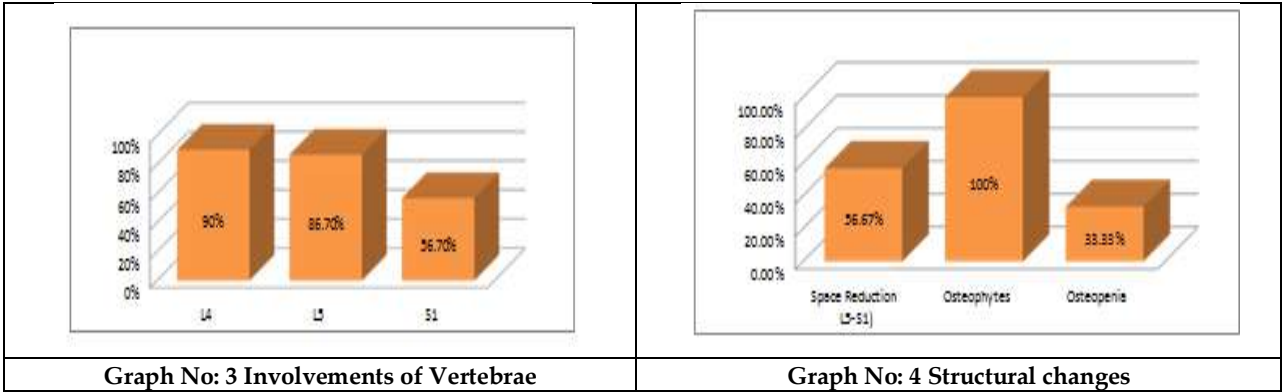
Table 10: Distribution of subjects according to Other Structural Changes

Structural Changes	No of patients	Total n %
Osteophytes	30	100 %
Osteopenia	10	33.33 %
Listhesis	1	3.33 %
Loss of Lumbar Lordosis	2	6.66 %





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Synthesis and Spectral Hammett Correlation Study of Some Substituted 2-Benzylidene-1-Tosylhydrazines

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ABSTRACT

A series containing ten 2-benzylidene-1-tosylhydrazines were synthesized by Fly-ash fly-ash: H_3PO_4 aided condensation of 1-tosylhydrazine and substituted benzaldehydes under microwave irradiation. These 2-benzylidene-1-tosylhydrazines compounds were characterized by physical constants, UV-Visible, FT-IR, 1H & ^{13}C -NMR spectral





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data. The group frequencies of infrared $\nu(\text{cm}^{-1})$ of $\text{C}=\text{N}$, $\nu\text{SO}_2(\text{sym})$, $\nu\text{SO}_2(\text{asym})$, $\nu\text{N-H}$, NMR chemical shifts (δ , ppm) of N-H , C-H , CH_3 and $\text{C}=\text{N}$ of these hydrazine derivatives were correlated with Hammett sigma constants, Swain-Lupton's F and R parameters using single and multi-regression analyses.

Keywords: 2-Benzylidene-1-tosylhydrazines, Fly-ash: H_3PO_4 , IR and NMR Spectra, Correlation analysis, Swain-Lupton parameter

INTRODUCTION

Now-a-days hydrazine are considered to be various and good pharmaceutical applications in the chemistry and biological chemistry field[1, 2]. The hydrazine derivatives exhibit a wide-ranging interesting pharmaceutical derivatives and are also used for important intermediates in organic synthesis[3]. Because, the growing requisite for environmentally responsible means of preparing a wide diversity of chemical products demanded by society drives the quest for synthetic efficiency. For the condition of the environment, in order to minimize the utility of underdone resources and waste production, a chemical reaction should proceed with high levels of step and low cost is important[4, 5]. For the present world wanted, an ideal chemical synthesis takes place in quantitative yield, with complete control of chemo-, regio- and stereo selectivity, without by products. The synthesized hydrazine derivatives have some biological activities notably trypanocidal potency on the parasite study[6]. Hydrazine derivatives behave as polydentate ligands, depend upon the naturally occupied groups present in the hydrazine unit. And also hydrazine their complexing properties may use for the drugs based on presenting transition metals. Some glycosyl phenylhydrazones and oximes were made and respectively, proving the existence of aldehydes in molecules[7, 8]. Sulphur hydrazides exhibit a great interest owing to their importance in synthesis a variety of valuable heterocyclic compounds which have pharmaceutical activities and chemotherapeutic value[9-12] against cognitive disorder because the existence of sulphur atom. In this perspective, the high synthetic potential of unsaturated systems has made possible for the wide-spread variety of cyclic building blocks[13]. Hydrazine derivatives are also used as analytical reagents, a polymer coating of ink, pigments and fluorescent materials[14]. Many greener catalysts were used for the efficient synthesis of hydrazine compounds by using SOCl_2 -Ethanol as catalyst was used[15, 16]. Rajarajan et al., studied the linear regression analyses on the substituted (*E*)-1-benzylidene-2-(4-bromophenyl)hydrazines and (*E*)-1-benzylidene-2-(4-chlorophenyl)hydrazines[17, 18]. Manikandan et al. have investigated the regression analyses on the (*E*)-*N*-(1-(substituted phenyl)ethylidene) benzo hydrazides, (*E*)-1-Benzylidene-2-(diphenylmethylene) hydrazines and (*E*)-2-(1-phenylethylidene)-1-tosylhydrazines[19,20]. In this contemporary study is mainly focused to correlated the spectral data of hydrazines with Hammett sigma constants employing statistical-regression analysis. From the statistical work results the probability of the substituent effects of substituents were predicted.

EXPERIMENTAL

General Procedure for preparation of aryl hydrazides [16, 21]

Appropriate stoichiometric quantities of 1-tosylhydrazine (100mmol) and *meta* and *para* substituted benzaldehydes (100mmol) and 0.5 g of fly-ash: H_3PO_4 nano-catalyst were microwaves in a Microwave Oven (**Scheme1**) at 120°C by means of 30s interval time (Ragotech, RG 31L Scientific Microwave Oven, 230 V A/C, 50 Hz, 2450 Hz, 1200 rpm (beam reflector)). After the treatment of the reaction mixture, it gave 95 % of the respective hydrazines. The spectroscopic data of synthesized 2-benzylidene-1-tosylhydrazines are utilized for the examination of purity and are given in Table 1.

RESULTS AND DISCUSSION

In the contemporary work, the spectral-linearity of made 2-benzylidene-1-tosylhydrazines has been studied by assessing the substituent effects. The perceived spectral data for the benzohydrazides, UV $\lambda_{\text{max}}(\text{nm})$, infrared $\nu\text{C}=\text{N}$,





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$\nu\text{SO}_2(\text{sym})$, $\nu\text{SO}_2(\text{asym})$, $\nu\text{N-H}$, the chemical shifts $\delta(\text{ppm})$ of N-H, C-H, CH_3 and C=N were correlated with various sigma constants [22-26].

UV spectral study

The measured UV absorption maxima (λ_{max} nm) values of the made 2-benzylidene-1-tosylhydrazines were recorded and presented in above. Regressions of these data against Hammett sigma constants, F and R parameters [22-26]. The statistical form of Hammett equation applied for the statistical evaluation is shown in equation (1).

$$\lambda = \rho\sigma + \lambda_0 \quad \dots(1)$$

where λ_0 is the maximum absorption for the parent member of the series. From the Table 2, it is evident that the UV absorption maxima (λ_{max} nm) values of except 3- NO_2 substituent of substituted 2-benzylidene-1-tosylhydrazine compounds with Hammett sigma constant σ_1 (0.906) and F (0.966) parameter give satisfactory correlations. The substituent constants σ , σ^+ , σ_R and R factors fails in correlations ($r < 0.900$). This is endorsed by the polar and resonance possession of substituents not obey the Hammett equation and the corresponding conjugative structure as displayed in Figure 1. Except σ_R , all constants gave positive ρ values. This designates the casual substituent effect operated in 2-benzylidene-1-tosylhydrazine compounds. Approximate number of mono-regressions failed and they show satisfactory correlation through multi-linear regressions with Swain-Lupton's [27] and the observed correlation equations are shown in (2) and (3).

$$\lambda_{\text{max}} (\text{nm}) = 271.98(\pm 5.7900) + 31.3610(\pm 11.6241)\sigma_1 - 18.2898(\pm 12.6158)\sigma_R \quad \dots(2)$$

($R = 0.973$, $n = 10$, $P > 95\%$)

$$\lambda_{\text{max}} (\text{nm}) = 275.06(\pm 6.2881) + 29.1058(\pm 12.3494)F - 0.5868(\pm 7.2660)R \quad \dots(3)$$

($R = 0.966$, $n = 10$, $P > 95\%$)

IR spectral study

The consigned infrared frequencies (cm^{-1}) of $\nu\text{C=N}$, $\nu\text{SO}_2(\text{sym})$, $\nu\text{SO}_2(\text{asym})$, $\nu\text{N-H}$ of substituted 2-benzylidene-1-tosylhydrazines are exist in Table 1. The measured infrared frequencies were utilized for regression analysis [22-26] and the mathematical form of Hammett equation was shown in (4).

$$\nu = \rho\sigma + \nu_0 \quad \dots(4)$$

where ν_0 is the frequency for the parent member of the series.

IR Spectral Correlation of $\nu\text{C=N}$ (cm^{-1})

From the Table 2, it is evident that the IR frequencies of $\nu\text{C=N}$ (cm^{-1}) all substituted 2-benzylidene-1-tosylhydrazine compounds with Hammett sigma constant σ (0.906) give satisfactory correlations. Except 4-F substituent of substituted 2-benzylidene-1-tosylhydrazine compounds with σ_1 ($r = 0.906$) give satisfactory correlations. However, IR $\nu\text{C=N}$ (cm^{-1}) frequencies 2-benzylidene-1-tosylhydrazine compounds fails in correlation against σ^+ , σ_R and F and R parameters ($r < 0.900$). This is happened by feeble polar, resonance and field effects substituents and the corresponding conjugative structure as displayed in Figure 1. Here negative ρ values obtained in all statistical operations and reversal of substituent effect takes place.

IR Spectral Correlation of $\nu\text{SO}_2(\text{sym})$ (cm^{-1})

From the Table 2, it is evident that the IR $\nu\text{SO}_2(\text{sym})$ (cm^{-1}) frequencies of made 2-benzylidene-1-tosylhydrazine compounds were fail in single statistical regressions along with negative ρ values. Reason for this is already stated above along with the conjugative structure as displayed in Figure 1. This inferred that the reversal effect of substituents operated in all compounds.

IR Spectral Correlation of $\nu\text{SO}_2(\text{asym})$ (cm^{-1})

From the Table 2, a satisfactory correlation coefficient was perceived for the IR $\nu\text{SO}_2(\text{asym})$ (cm^{-1}) frequency values of except 3-OH and 4-OH substituents of substituted 2-benzylidene-1-tosylhydrazines σ ($r = 0.902$) and σ^+ ($r = 0.901$). The same was failed in the constants σ_1 , σ_R , F and R factors ($r < 0.900$). Here, the regression exists positive ρ values except σ^+ and R parameter. Reasons stated earlier for failed regressions and the conjugative structure was displayed in Figure 1.



Manikandan *et al.*,**IR Spectral Correlation of $\nu\text{N-H}(\text{cm}^{-1})$**

From the Table 2, it is evident that the IR $\nu\text{N-H}(\text{cm}^{-1})$ frequency values of except 2-Cl substituent of substituted 2-benzylidene-1-tosylhydrazine compounds created agreeable correlation co-efficient for Hammett sigma σ_R ($r=0.902$) constant. However, the IR frequency $\nu\text{N-H}(\text{cm}^{-1})$ values of 2-benzylidene-1-tosylhydrazines compounds with Hammett σ , σ^+ , σ_I , F and R constraints were fails in regression ($r < 0.900$). Reasons stated earlier and the conjugative structure as displayed in Figure1 leads to fails in the regressions. Here negative ρ values exists for σ and σ_R parameter and it inferred the reversal of correlations in substituted 2-benzylidene-1-tosylhydrazines compounds. While looking the multi-regression analysis with Swain-Lupton's [27] parameters, there is a satisfactory correlations were observed and are shown in the equations (5) to (12).

$$\nu\text{C=N}(\text{cm}^{-1}) = 1573.62(\pm 22.5709) - 87.9954(\pm 45.3134)\sigma_I - 44.6426(\pm 49.1790)\sigma_R \quad \dots(5)$$

($R = 0.965$, $n = 10$, $P > 95\%$)

$$\nu\text{C=N}(\text{cm}^{-1}) = 1574.07(\pm 26.4610) - 66.2770(\pm 51.9674)F - 1.6081(\pm 30.5760)R \quad \dots(6)$$

($R = 0.946$, $n = 10$, $P > 90\%$)

$$\nu\text{SO}_2(\text{sym})(\text{cm}^{-1}) = 1164.82(\pm 7.5644) - 13.1606(\pm 15.1864)\sigma_I + 2.1043(\pm 16.4819)\sigma_R \quad \dots(7)$$

($R = 0.938$, $n = 10$, $P > 90\%$)

$$\nu\text{SO}_2(\text{sym})(\text{cm}^{-1}) = 1164.82(\pm 7.7253) - 6.3071(\pm 15.1720)F - 0.5667(\pm 8.9267)R \quad \dots(8)$$

($R = 0.915$, $n = 10$, $P > 90\%$)

$$\nu\text{SO}_2(\text{Asym})(\text{cm}^{-1}) = 1327.31(\pm 16.4202) + 30.6133(\pm 32.9651)\sigma_I - 1.4158(\pm 35.7774)\sigma_R \quad \dots(9)$$

($R = 0.933$, $n = 10$, $P > 90\%$)

$$\nu\text{SO}_2(\text{Asym})(\text{cm}^{-1}) = 1319.33(\pm 14.7134) + 34.8353(\pm 28.8961)F - 18.7761(\pm 17.0018)R \quad \dots(10)$$

($R = 0.952$, $n = 10$, $P > 95\%$)

$$\nu\text{N-H}(\text{cm}^{-1}) = 3210.7(\pm 30.6054) - 28.7828(\pm 61.4433)\sigma_I + 48.1146(\pm 66.6849)\sigma_R \quad \dots(11)$$

($R = 0.989$, $n = 10$, $P > 95\%$)

$$\nu\text{N-H}(\text{cm}^{-1}) = 3194.5160(\pm 31.3145) - 11.1116(\pm 61.4992)F - 5.4632(\pm 36.1842)R \quad \dots(12)$$

($R = 0.909$, $n = 10$, $P > 90\%$)

NMR spectral study

In nuclear magnetic resonance spectra, the proton and the ^{13}C chemical shifts (δ , ppm) depends on the electronic environment of the nuclei concerned. The allocated chemical shifts (δ , ppm) have been subjected to single regression analysis with reactivity parameters [22-26] through Hammett equations as in (13)

$$\delta = \rho\sigma + \delta_0 \quad \dots(13)$$

where δ_0 is the δ chemical shifts (δ , ppm) for the parent member of the series.

 ^1H NMR Spectral Correlation **^1H NMR Spectral Correlations of N-H (ppm)**

From the Table 2, the assigned N-H chemical shifts (δ ppm) values of except parent, 2- NO_2 and 3- NO_2 substituents of substituted 2-benzylidene-1-tosylhydrazines compounds exhibits satisfactory linear regression for σ_I ($r=0.904$). Except parent and 3- NO_2 substituent of substituted 2-benzylidene-1-tosylhydrazines produced acceptable regression co-efficient for F ($r=0.904$) parameter. However, the N-H chemical shifts (δ ppm) ^1H NMR values of 2-benzylidene-1-tosylhydrazines compounds with σ , σ^+ , σ_R and R factors fails in regressions ($r < 0.900$). Failed regression analysis is due to the reasons mentioned in earlier and the conjugative structure as displayed in Figure 1. Regressions exhibits positive ρ values except σ_R and R parameter. It inferred that the normal substituent consequence-effect operates maneuvers in 2-benzylidene-1-tosylhydrazines compounds.

 ^1H NMR Spectral Correlations of C-H (ppm)

From the Table 2, the assigned C-H chemical shifts (δ ppm) values of except 3-OH, 4-OH and 4- CH_3 substituents of substituted 2-benzylidene-1-tosylhydrazines compounds exhibits casual regression co-efficient σ constant ($r=0.936$). Similarly, except 4-OH and 4- CH_3 substituents of substituted 2-benzylidene-1-tosylhydrazines compounds exhibits casual regression co-efficient constant σ^+ ($r=0.910$). The σ_I constants produced acceptable regression co-efficient





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($r=0.920$) except 2-Cl, 4-F and 4-CH₃ substituents. Except 3-OH and 4-OH substituents of substituted 2-benzylidene-1-tosylhydrazines compounds exhibits regression co-efficient for σ_R ($r=0.903$) constants. However, the ¹H NMR –C-H chemical shifts (δ , ppm) values 2-benzylidene-1-tosylhydrazines compounds with F and R factors were failed in regression ($r < 0.900$). The pathetic F and R factors and conjugative structure in Figure1 were leads to fails in regressions. Majority regressions exhibits positive ρ values except R parameter.

¹H NMR Spectral Correlations of -CH₃ (ppm)

From the Table 2, the assigned –CH₃ chemical shifts (δ ppm) values of except 4-F and 4-OH substituents of substituted 2-benzylidene-1-tosylhydrazines exhibits acceptable regression coefficient for σ_R ($r=0.903$) constant. Except parent and 4-OH substituents of substituted 2-benzylidene-1-tosylhydrazines exhibits reasonable regression co-efficient for F ($r=0.909$) parameter. Except 4-OH substituent of substituted 2-benzylidene-1-tosylhydrazines exposed casual regression co-efficient for R ($r=0.910$) parameter. However, the ¹H NMR –CH₃ chemical shifts (δ ppm) of 2-benzylidene-1-tosylhydrazines compounds failed for σ , σ^+ and σ_I ($r < 0.900$) constants. Failed regression is associated with the reasons stated already and the conjugative structure as displayed in Figure1. Selective regressions exposed positive ρ values except σ , σ^+ and σ_R constants. It designates that the casual substituent effects operated in substituted 2-benzylidene-1-tosylhydrazines compounds. While looking the multi-regression analysis with Swain-Lupton's parameters [27], there is a satisfactory correlations are observed as in the following equations (14) to (19).

$$\delta N-H(\text{ppm}) = 9.5696(\pm 0.1518) + 0.4069(\pm 0.3048)\sigma_I - 0.2452(\pm 0.3308)\sigma_R \quad \dots(14)$$

($R = 0.947$, $n = 10$, $P > 90\%$)

$$\delta N-H(\text{ppm}) = 9.5986(\pm 0.1538) + 0.3657(\pm 0.3022)F - 0.0624(\pm 0.1778)R \quad \dots(15)$$

($R = 0.942$, $n = 10$, $P > 90\%$)

$$\delta C-H(\text{ppm}) = 8.3668(\pm 0.2341) + 0.3380(\pm 0.4700)\sigma_I + 0.4607(\pm 0.5101)\sigma_R \quad \dots(16)$$

($R = 0.942$, $n = 10$, $P > 90\%$)

$$\delta C-H(\text{ppm}) = 8.2629(\pm 0.2460) + 0.3375(\pm 0.4832)F - 0.0596(\pm 0.2843)R \quad \dots(17)$$

($R = 0.926$, $n = 10$, $P > 90\%$)

$$\delta CH_3(\text{ppm}) = 2.3971(\pm 0.0380) + 0.0026(\pm 0.0764)\sigma_I - 0.0069(\pm 0.0829)\sigma_R \quad \dots(18)$$

($R = 0.903$, $n = 10$, $P > 90\%$)

$$\delta CH_3(\text{ppm}) = 2.3969(\pm 0.0161) + 0.0161(\pm 0.0727)F + 0.0128(\pm 0.0427)R \quad \dots(19)$$

($R = 0.945$, $n = 10$, $P > 90\%$)

¹³C NMR Spectral Correlation

¹³C NMR Spectral Correlations of C=N (ppm)

From the Table 2, the assigned C=N chemical shifts (δ ppm) of substituted 2-benzylidene-1-tosylhydrazines failed in regression ($r < 0.900$) for sigma constants, F and R factors. The reason for failed regression was stated already along with the conjugative structure d displayed in Figure1. Entire regressions produced positive ρ values except σ_R . Here the normal effect of substituents circulates in 2-benzylidene-1-tosylhydrazines.

¹³C NMR Spectral Correlations of CH₃ (ppm)

From the Table 2, the assigned –CH₃ chemical shifts (δ , ppm) values of 2-benzylidene-1-tosylhydrazines were fails in regression ($r < 0.900$) sigma constants, F and R parameter. A feeble I, R and F factors and the conjugative structure illustrated in Figure1 were sleeps for finding the regression co-efficients. Except resonance component, all regression produced negative ρ values and it referred to reversed substituent effects in whole 2-benzylidene-1-tosylhydrazines compounds. The multi regression investigations with Swain-Lupton's parameters [27] formed agreeable correlation co-efficients with the following equations (20) to (23).

$$\delta C=N(\text{ppm}) = 127.65(\pm 0.1616) + 0.3999(\pm 0.3246)\sigma_I - 0.2571(\pm 0.3522)\sigma_R \quad \dots(20)$$

($R = 0.945$, $n = 10$, $P > 90\%$)

$$\delta C=N(\text{ppm}) = 127.73(\pm 0.1693) + 0.2891(\pm 0.3326)F - 0.0065(\pm 0.1957)R \quad \dots(21)$$

($R = 0.931$, $n = 10$, $P > 90\%$)

$$\delta CH_3(\text{ppm}) = 21.5927(\pm 0.0641) - 0.1551(\pm 0.1288)\sigma_I + 0.0515(\pm 0.1398)\sigma_R \quad \dots(22)$$

($r = 0.914$, $n = 10$, $P > 90\%$)





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$$\delta\text{CH}_3 \text{ (ppm)} = 21.5749(\pm 0.0661) - 0.0920(\pm 0.1298)F + 0.0398(\pm 0.0763)R \quad \dots(23)$$

(R = 0.920, n = 10, P > 90%)

CONCLUSION

A series of ten numbers of substituted 2-benzylidene-1-tosylhydrazines were made through the green condensation of 1-tosylhydrazine and *meta* and *para* substituted benzaldehydes. The purities of these substituted 2-benzylidene-1-tosylhydrazines analyzed from their physical constants, spectral data reported in the literature. The UV, FT-IR, NMR spectral data of these 2-benzylidene-1-tosylhydrazines were utilized for regression analysis against Hammett sigma constants, F and R factors. Many single regression and multi-regressions produced agreeable correlation coefficients.

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Table-1. The ultraviolet absorption maxima (λ_{max} , nm), infrared absorptions (ν , cm^{-1}) and NMR chemical shifts (δ , ppm) spectral values of substituted 2-benzylidene-1-tosylhydrazines

S. No.	X	UV (λ_{max} , nm)	IR ν (cm^{-1})				1H NMR (δ , ppm)			^{13}C NMR (δ , ppm)	
			C=N	SO_2 (sym)	SO_2 (asym)	N-H	N-H	C-H	CH_3	C=N	CH_3
1	H	279.0	1591.27	1168.86	1307.74	3219.19	9.9611	8.1170	2.4288	127.96	21.57
2	3-Br	299.0	1521.84	1166.93	1344.38	3194.12	9.8920	8.2742	2.3847	127.94	21.58
3	2-Cl	293.0	1568.13	1136.07	1305.81	3080.32	9.8864	8.0462	2.3534	128.32	21.36
4	4-Cl	295.0	1510.26	1161.15	1325.10	3207.62	9.7662	8.2680	2.3743	127.79	21.51
5	4-F	304.5	1597.06	1168.86	1330.88	3186.40	9.9893	8.0324	2.4148	127.96	21.62
6	3-OH	279.0	1516.05	1159.22	1367.74	3221.12	9.7929	8.7468	2.3400	127.79	21.45
7	4-OH	279.0	1560.41	1170.79	1357.89	3197.98	9.6684	8.6554	2.5003	127.77	21.49
8	4- CH_3	270.5	1597.06	1168.86	1330.88	3188.33	9.2212	8.2994	2.3677	127.39	21.68
9	2- NO_2	290.0	1506.41	1165.00	1361.74	3211.48	9.8110	8.7884	2.4480	127.78	21.49





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10	3- NO ₂	279.0	1514.12	1159.22	1357.89	3211.48	9.6446	8.9266	2.3815	127.79	21.51
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Table-2. The results of statistical analysis of ultraviolet absorption maxima (λ_{max} , nm), infrared absorptions (ν , cm^{-1}) and NMR chemical shifts (δ ppm) of substituted 2-benzylidene-1-tosylhydrazines with Hammett constants σ , σ^+ , σ_I , σ_R and F and R parameters.

Frequency	Constants	r	I	q	s	n	Correlated derivatives
λ_{max}	σ	0.832	285.08	9.331	11.06	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.831	286.48	7.510	10.73	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.906	276.08	28.642	8.98	9	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂
	σ_R	0.826	284.63	-	11.24	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.966	275.27	29.027	8.70	9	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂
	R	0.802	287.03	0.769	11.65	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
$\nu C=N$	σ	0.906	1560.43	-	31.29	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.833	1549.26	-	38.13	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.906	1583.65	-	32.45	9	H, 3-Br, 2-Cl, 4-Cl, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ , 3-
	σ_R	0.835	1538.11	-	38.08	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.843	1574.65	-	36.61	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.805	1546.80	-4.681	40.61	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
$\nu SO_{2(sym)}$	σ	0.822	1163.65	-6.318	10.53	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.836	1162.76	-6.313	10.13	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.830	1167.30	-	10.30	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_R	0.800	1162.46	-0.199	10.82	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.815	1165.03	-6.383	10.69	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.803	1162.22	-0.859	10.82	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
$\nu SO_{2(asym)}$	σ	0.902	1336.38	14.222	23.01	8	H, 3-Br, 2-Cl, 4-Cl, 4-F, 4-CH ₃ , 2-NO ₂ , 3-NO ₂
	σ^+	0.901	1339.27	-6.307	23.38	8	H, 3-Br, 2-Cl, 4-Cl, 4-F, 4-CH ₃ , 2-NO ₂ , 3-NO ₂
	σ_I	0.833	1327.63	30.402	22.33	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_R	0.803	1339.67	3.943	23.67	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.836	1326.17	32.319	22.06	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.836	1333.66	-	22.37	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
$\nu N-H$	σ	0.806	3190.41	7.555	43.41	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.820	3192.44	-	42.56	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.824	3199.89	-	43.14	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_R	0.902	3199.08	43.075	42.27	9	H, 3-Br, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ , 3-
	F	0.807	3196.50	-	43.39	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.802	3189.94	-5.978	43.42	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
$\delta N-H$	σ	0.822	9.738	0.134	0.22	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.824	9.759	0.094	0.22	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.904	9.624	0.370	0.21	7	3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃
	σ_R	0.817	9.733	-0.174	0.23	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.904	9.621	0.357	0.21	8	3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂
	R	0.808	9.749	-0.045	0.23	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
$\delta C-H$	σ	0.936	8.354	0.331	0.32	7	H, 3-Br, 2-Cl, 4-Cl, 4-F, 2-NO ₂ , 3-NO ₂
	σ^+	0.900	8.415	0.005	0.35	8	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 2-NO ₂ , 3-NO ₂
	σ_I	0.920	8.263	0.406	0.33	7	H, 3-Br, 4-Cl, 3-OH, 4-OH, 2-NO ₂ , 3-NO ₂
	σ_R	0.903	8.503	0.519	0.33	8	H, 3-Br, 2-Cl, 4-Cl, 4-F, 4-CH ₃ , 2-NO ₂ , 3-NO ₂

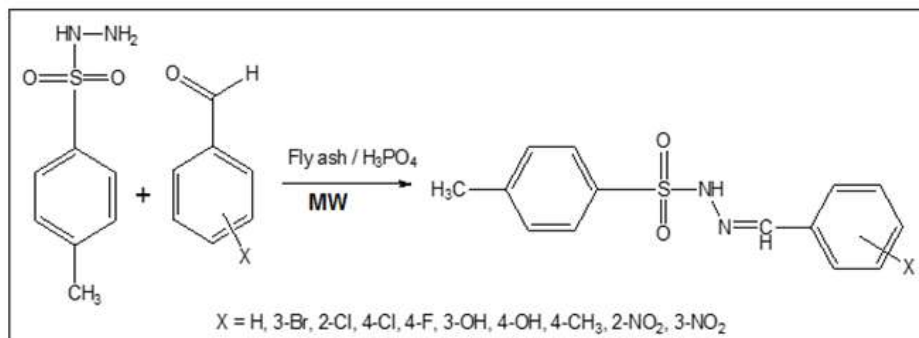




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	F	0.822	8.284	0.329	0.34	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.805	8.401	-0.043	0.35	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
δ CH ₃	σ	0.813	2.40	-0.018	0.05	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.812	2.40	-0.016	0.05	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.800	2.39	0.001	0.05	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_R	0.903	2.39	-0.006	0.05	8	H, 3-Br, 2-Cl, 4-Cl, 3-OH, 4-CH ₃ , 2-NO ₂ , 3-NO ₂
	F	0.909	2.39	0.017	0.05	8	3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-CH ₃ , 2-NO ₂ , 3-NO ₂
	R	0.910	2.40	0.013	0.05	9	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-CH ₃ , 2-NO ₂ , 3-NO ₂
δ C=N	σ	0.810	127.82	0.107	0.24	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.833	127.84	0.135	0.23	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.838	127.71	0.361	0.22	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_R	0.818	127.81	-0.187	0.24	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.834	127.73	0.288	0.23	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.801	127.85	0.006	0.24	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
δ CH ₃	σ	0.802	21.53	-0.045	0.09	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ^+	0.812	21.52	-0.020	0.09	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_I	0.836	21.58	-0.147	0.08	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	σ_R	0.806	21.53	0.024	0.09	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	F	0.824	21.56	-0.086	0.09	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,
	R	0.816	21.53	0.035	0.09	10	H, 3-Br, 2-Cl, 4-Cl, 4-F, 3-OH, 4-OH, 4-CH ₃ , 2-NO ₂ ,

r = Correlation co-efficient; q = slope; I = Intercept; s = Standard deviation; n = Number of substituents



Scheme 1. Synthesis of substituted 2-benzylidene-1-tosylhydrazines

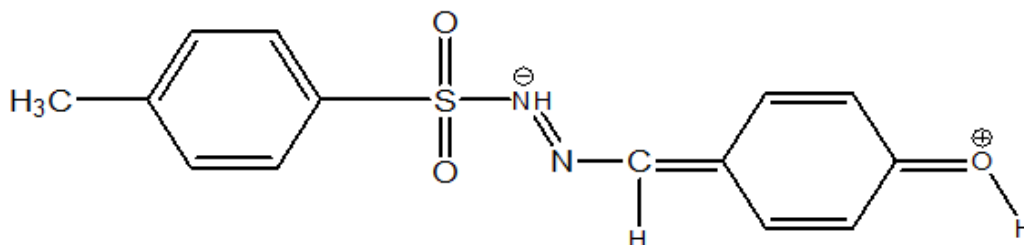


Figure 1. Resonance conjugative structure





Effect of Two Geomagnetic Storms on TEC at EIA Region Bhopal during the Ascending Phase of the 25th Solar Cycle

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ABSTRACT

The multi frequency GPS satellite data obtained at Bhopal (23.2° N, 77.4° E & MLAT 14.2° N) India were analysed to study the vertical total electron content (VTEC) changes during the strong geomagnetic storms occurred on March 23-24, 2023 (Dst = -163 nT) and April 23-24, 2023 (Dst = -213 nT) i.e. ascending phase of 25th solar cycle. Positive and negative deviation with VTEC has been observed for both strong geomagnetic storms. A positive deviation on(+38%) in VTEC was observed at 0415 UT on March 24, 2023, while it is minimum (-76%) at 1533 UT on March 24, 2023. Similarly, positive deviation of +28% in VTEC was observed at 0300 UT on April 24, 2023, whereas it is minimum (-74%) was observed at 1705 UT on April 24, 2023. We compared the IRI 2020 TEC with the observed VTEC and found that it is well aligned with the storm occurred on March 24, 2023, while it is suppressed with the GPS-VTEC for April 21-25, 2023 during the main phase of storm. Generally, IRI TEC has been underestimate with GPS VTEC during the different phases of the occurred strong geomagnetic storms. The results are compared with the earlier observations and possible mechanism is also discussed.

Keywords: Vertical Total Electron Content (VTEC); Equatorial Ionization Anomaly (EIA); Ionospheric Disturbance; Geomagnetic Storms; IRI- 2020.





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INTRODUCTION

It is well known that the ionosphere is a non-uniform and anisotropic atmospheric layer that ranges between 80 and 1500 km from the Earth's surface. This layer contains gases from the ionized plasma by changing its state owing to the solar radiation. The ions and electrons are formed as pairs owing to ionization. Free and mobile electrons affect electromagnetic signals depending on their frequency. Ionospheric variation is influenced by space weather events, such as solar winds, solar flares, and geomagnetic storms. Disturbed space weather conditions trigger unexpected irregular changes in the magnetosphere-ionosphere-thermosphere system. Geomagnetic storms are extreme space weather events that have considerable impacts on the ionosphere and power transmission systems. Geomagnetic storms are large disturbances in the geomagnetic field that last from several hours to days. This produces a global disturbance in the Earth's magnetic field, which usually occurs owing to abnormal conditions in the interplanetary magnetic field (IMF) and solar wind plasma emissions caused by various solar phenomena. Furthermore, the magnitude of these geomagnetic effects largely depends on the configuration and strength of potentially geoeffective solar/interplanetary features. The storms are characterized by enhanced magnetospheric and ionospheric current systems (Gonzalez et al., 1994; Lühr et al., 2017). However, several current systems contribute to different ground magnetic field disturbances (or geomagnetic storms) at different latitudes. Therefore, storms at low, mid, and high latitudes are usually represented by indices such as disturbance storm-time (Dst), Kp, and AE, respectively (Love & Gannon, 2009). Storms at low latitudes arise mainly from enhanced solar wind-magnetosphere coupling and ionosphere-ring current coupling due to solar storms (Daglis, 1997; Ebihara et al., 2005). Due to geomagnetic disturbances such as geomagnetic storm sudden impulse (SI) or sudden commencements (SSCs), the magnetospheric electric field is transferred to the magnetic equator from auroral latitudes through mid-latitudes (Gillies et al., 2012; Shinbori et al., 2014; Haridas et al., 2024), and the distribution of ionospheric plasma is affected by perturbations in the field. Throughout the day, the prompt penetration electric field is eastward and amplifies the dynamo electric field. This dynamo electric field enhances the vertical $E \times B$ plasma drift by lifting the plasma to higher altitudes (Rastogi and Klobuchar 1990, Chakraborty et al., 2015). During the day, the prompt penetration electric field (PPEF) is eastward, and at night, westward (Huang et al., 2005; Sastri et al., 1997; Sastri et al., 1992). Among severe storm periods, strong eastward PPEF and super fountains are built up due to the cause of fast neutral wind, which may shift the crest of the equatorial ionization anomaly (EIA) up to $\pm 30^\circ$ latitudes (Balan et al., 2011).

The impact of geomagnetic storms is accidental in various aspects, such as the dayside compression of the magnetosphere (Borovsky & Denton, 2016; Cattell et al., 2017), increase of magnetospheric currents (Ganushkina et al., 2017; Stepanova et al., 2019), depletion and enhancement of trapped particles in the radiation belts (Moya et al., 2017; Tuner et al., 2015; Turner et al., 2019), intensification of precipitation in the auroral regions (Longden et al., 2008), qualifications in the dynamics and properties of the ionosphere, and geomagnetically induced currents on the Earth's surface (Shi et al., 2008). The TEC response to the geomagnetic storm has been reported for the station near the crest of equatorial anomaly by several authors (Bagiya et al., 2009; Dashora et al., 2007; Manju et al., 2009; Sreeja et al., 2009; Jain et al., 2010; Trivedi et al., 2011 and references therein) using GPS and ionosonde data. The TEC response to the geomagnetic storm of May 15, 2005, at Udaipur, (24.73° N, 73.73° E and GMLAT 16.12° N) India, was studied by Dashora et al. (2009), and they found that the large enhancement in vertical TEC is attributable to the prompt penetration of electric fields. The geomagnetic storm that occurred in Rajkot, (22.29° N, 70.74° E and GMLAT 13.99° N) India, was studied by Bagiya et al. (2009) at the August 24, 2005 station using GPS TEC and found that the enhancement in VTEC is attributable to prompt penetration of electric fields during the storm day, and suppression in VTEC on the subsequent recovery day is due to disturbance dynamo electric fields and thermospheric composition changes. The storm of May 15, 2005, and August 24, 2005, for Bhopal using GPS TEC data was studied by Jain et al., 2010, and it was found that the under-shielding and over-shielding conditions and peak-like structure in the EIA region were the reasons for the prompt penetration of the electric field, which was observed for both storms. Trivedi et al., (2011) studied the 21 storms of 2005-2007, for Bhopal using GPS TEC data. They also found that the suppression in VTEC was observed on August 25, 2005, which was mainly due to the thermospheric composition changes and possibly due to the disturbance dynamo electric fields. The equatorial and low-latitude ionospheres



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exhibit remarkable behaviors, which have been a subject of immense interest for the ionospheric community, including equatorial ionization anomaly (EIA), equatorial electrojet (EEJ), equatorial spread-F (ESF), etc. (Chkraborty et al., 2015). Recently, the storm-induced responses of ionospheric total electron content (TEC) over the Indian region and Atlantic-Pacific Ocean sectors were studied by Simi et al. (2021) and Akala et al. (2011), respectively. They assumed that PPEFs triggered ionospheric irregularities during the main phase of storms. Positive (negative) ionospheric storms are defined as the increase (decrease) in ionospheric metrics such as peak electron density (N_{\max}), electron density (N_e), and TEC from their respective quiet-time values caused by geomagnetic storms. The magnitude and characteristics (whether positive or negative) of ionospheric storms depend on the latitude (Shreedevi & Choudhary, 2017), local time (Maruyama et al., 2004), and phases of geomagnetic storms (Pedatella et al., 2009; Haridas et al., 2024). The International Reference Ionosphere (IRI) is an empirical model based on data from the worldwide network of ionosonde stations, incoherent scatter radars (at Jicamarca Arecibo, Millstone Hill, Malvern, and St. Santin) and has been widely accepted as a reliable ionospheric model (Sahu et al., 2021) used by the scientific community. Several studies have been conducted comparing IRI-TEC and GPS-VTEC over different regions, and the IRI model has been steadily improved from IRI-78 to IRI-2016 (Rawer et al., 1978; Bilitza, 1986, 1990, 2001; Bilitza and Reinisch, 2008; Bilitza et al., 2014) and now IRI-2016 (Bilitza et al., 2017), and the latest is IRI-2020 (Bilitza et al., 2022).

Sahu et. al. (2021) compared GPS-VTEC with IRI-TEC for quiet days during the study period of May 2016 to August 2017 and observed that IRI-TEC consistently underestimated GPS-TEC across all months during the study period. Furthermore, He et. al. (2023) evaluated the ionospheric response over China using TEC data from the IRI-2020 model and the GNSS-GIM model. Yang et al. (2023) conducted a statistical analysis of latitude-dependent variations over mainland China using TEC data and the IRI-2020 model. Mridula et al., (2024), the ionospheric response over the equatorial region India was compared and analysed using TEC data from the IRI-2020 and TIE-GCM models, revealing that IRI-TEC underestimated the observed GPS-TEC. Recently, Jain et al. al. (2024) Compared the IRI-2020 model and the GPS-VTEC model for super-intense geomagnetic storms occurred on 10-11 May, 2024 at Bhopal. The procedure of monitoring the ionosphere with the Global Positioning System (GPS) is currently widely used. GPS is an effective tool to investigate ionospheric structure owing to its continuous operation and the large number of worldwide receivers, mainly during magnetically disturbed periods when dynamics and energy dissipation processes in the magnetosphere–thermosphere–ionosphere system become extremely complex (Liu et al., 2002, Trivedi et al., 2011). In the last three decades, many authors have studied several individual measurements of TEC variation with local time, season, and solar activity. Since the past few decades many authors using different techniques observed and reported the ionospheric response to geomagnetic storms at low and equatorial latitudes in the Indian longitude (Dabas et al., 1989; Dabas et al., 2006; Dashora and Pandey, 2007; Sreeja et al., 2009; Trivedi et al., 2011 and references therein). Chakraborty et. al. (2015) examined the impact of geomagnetic storms on the low-latitude ionosphere of the Indian equatorial region. They found that there was a significant increase in VTEC of up to 150% and a decrease of up to 72% throughout the storms of April 24 and July 15, 2012. Electron dynamic effects, such as PPEF and DDEF, as well as mechanical effects, such as storm-induced equatorward neutral wind and thermospheric composition changes, were observed. The electrodynamic effect of geomagnetic storms around the region is more effective than that at lower latitudes, and this was further confirmed by using the O/N₂ ratio and VTEC map, which was constructed from International GNSS Service (IGS) data.

Jain et. al., (2024) observed at Bhopal (23.2° N, 77.4° E & MLAT 14.2° N) for super-intense geomagnetic storms that occurred on May 10 to 11, 2024 (Sym-H: -518 nT) were studied using the (VTEC). It was observed that the super-intense geomagnetic storm produced positive and negative influences on the VTEC. They observed a +61 % deviation in VTEC at ~ 0500 UT on May 12, 2024, whereas (-68.5%) deviation in VTEC was observed at ~ 2045 UT on May 11, 2024. The increase in VTEC (+24% to 50%) during the main phase of the storm was attributed to the prompt penetration of electric fields (PPEFs), and the suppression of VTEC during the recovery phase of the storm was attributed to the changes in the thermospheric composition and ionospheric disturbance dynamo electric fields (DDEF). They also compared IRI-2020 TEC with the observed VTEC and found that the IRI-TEC model accurately estimated the suppression in TEC on May 11 and 12, but could not reflect the wave-like structure observed in VTEC on May 12, 2024. In this study, an attempt was made to study the effect of two geomagnetic storms that occurred on





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March 23, 2023 and April 23, 2023, that is, the rising phase of 25th solar cycle. The investigation aims to study the effect of storms on the low-latitude ionosphere, with the aid of GPS-based TEC measurement from an Equatorial Ionization Anomaly (EIA) Bhopal (23.2° N, 77.4° E & MLAT 14.2° N) station.

DATA AND METHOD OF ANALYSIS

To study the ionospheric variability and irregularities over a station near the crest of the equatorial ionization anomaly, a multi-frequency GPS receiver was installed at the Upper Atmospheric Laboratory of the Institute for Excellence in Higher Education (IEHE) in Bhopal (23.2° N, 77.4° E & MLAT 14.2° N) in April 2016. with the collaboration of the Space Physics Laboratory, VSSC Thiruvananthapuram, under its In-SWIM science program. The receiver tracks signals from the GPS, GLONASS, GALILEO, SBAS, COMPASS, and QZSS constellations of GNSS satellite systems. Each satellite is identified by a unique sequence of number called Pseudo Random Number (PRN). The multi frequency GPS receiver can track GPS signals at L1 (1575.42 MHz), L2 (1227.60 MHz), and L5 (1176.45 MHz) frequencies. The receiver generates and outputs 50-Hz phase and amplitude samples for all visible satellites and frequency bands. The TEC data are recorded every minute for all satellites tracked by the receiver. Amplitude and phase scintillation data along with satellite PRN, azimuthal angle, and elevation angle are also recorded simultaneously. We used TEC data for March 21-25, 2023 and April 21-25, 2023, recorded by a GPS receiver, and their responses to two geomagnetic storms are presented in this paper. The total electron content (TEC) is defined as the line integral of electron density on a given ray path. This slant TEC (STEC or simply TEC) corresponds to the total number of free electrons along a cylindrical path with a 1 m² cross-sectional area. The unit of TEC is equal to TECU, where 1 TECU is equal to 10¹⁶ electrons/m². When TEC is calculated on a vertical path in the local zenith direction, it is called the vertical total electron content (VTEC). STEC is converted to VTEC by assuming the penetration point of the satellite ray path with the ionospheric thin shell at a height of 350 km from the Earth's surface as follows:

$$VTEC = \cos \chi \cdot STEC$$

where χ is the angle of incidence at an altitude of 350 km of the GPS ray path from the satellite to the ground receiver, and $\cos \chi$, an oblique factor:

$$\cos \chi = \sqrt{1 - \left(\frac{R_E \cos \theta_e}{R_E + H_{iono}} \right)^2} \quad \dots\dots (1)$$

where R_E , is the radius of the earth; θ_e , the elevation angle of the satellite; and H_{iono} , the height of ionospheric penetration point (IPP) usually assumed to be 350-400 km. It follows that an IPP height of 350 km for the Indian region can be suitably used for vertical TEC calculation (Jain et. al., 2024, and references therein). To remove multipath errors, the data were filtered for elevation angles less than 30°. In order to study the effect of two geomagnetic storms on low-latitude TEC during the data of Interplanetary magnetic field (IMF Bz), Proton density (Np), Speed velocity (Vp), have been obtained from internet through (<http://omniweb.gsfc.nasa.gov/from/dx1.html>) and Sym-H, dsym-H/dt data for March and April 2023 were collected from the website of the World Data Center (WDC) for Geomagnetism, Kyoto. The response of the ionosphere to geomagnetic disturbance is most conveniently described in terms of Δ TEC (the percentage deviation of TEC) from the quiet time value (Jain et. al., 2024, and references therein).

$$\Delta TEC\% = \left[\frac{TEC_{disturb} - TEC_{quiet}}{TEC_{quiet}} \right] \times 100\% \quad \dots\dots (2)$$

Where $TEC_{disturb}$ = TEC on disturb day, TEC_{quiet} = TEC on quiet day

We restricted our analysis to over five days from the day of the main phase onset (MPO) and to four days subsequent to the MPO of the storm. In this paper, we present an analysis of TEC behavior and percentage deviation of TEC with respect to the average quiet day TEC of the month). We followed the Classification of geomagnetic storms characterised by Sugiura and Chapman 1960, and grouped as Extreme ($Dst_{min} < -350$ nT), Severe (-250 nT $\geq Dst_{min} \geq -350$ nT), Strong ($-100 \geq Dst_{min} \geq -250$ nT), and Moderate ($-50 \geq Dst_{min} \geq -100$ nT) and weak ($-30 \geq Dst \geq -50$).

IRI-2020 data set was download from <https://kauai.ccmc.gsfc.nasa.gov/instantrun/iri/> with default parameters for geographic latitude 23.2° N, 77.4° E (Bhopal) from March 21-25, 2023 & April 21-25, 2023. As this data set is of 1-hour interval, we also used the 1-hour average of VTEC for a better comparison with IRI-TEC (Jain et. al., 2024).





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RESULTS AND DISCUSSION

Geomagnetic condition

To study the impact of strong geomagnetic storms on the ionosphere, we selected two cases of storms that occurred on March 23, 2023 ($Dst_{min} = -163$ nT) and April 23, 2023 ($Dst_{min} = -213$ nT). The details of geomagnetic parameter variations during these storms are described in the following subsections.

Storm on March 23, 2023

The effect of strong geomagnetic storm occurred on March 23, 2023 is shown in Figure-1 (a-f) for the period March 21-25, 2023. The solar wind (proton) speed (V_p), proton density (N_p), IMF Bz, and Dst are shown in Figure-1 (a-d). The Vertical total electron content (VTEC) and percentage deviation of VTEC are given in Figure 1 (e-f), respectively. It is observed in Fig. 1(a) that the solar wind speed (V_p) was almost constant until 1100 UT on March 21, 2023, and then started increasing gradually, after which small amplitude fluctuations were observed from March 21, 2023 at 1700 UT to March 23, 2023, at 2350 UT, then it again started decreasing gradually and reached its minimum value of 412 km/s at 1600 UT on March 24, 2023. Subsequently, it again started increasing gradually and reached a maximum value of 586 km/s at 2000 UT on March 25, 2023. Fig. 1(b) illustrates two peaks (~ 30 cm⁻³) in solar wind density, around 1400 UT on March 23, 2023 and around 0800 UT on March 24, 2023 during main phase and recovery phase of the storm respectively. As shown in Fig. 1(c), After 0600 UT on March 21, 2023, the IMF Bz fluctuated with a small amplitude in the northward and southward directions and then turned southward at 0805 UT on March 23, 2023. IMF Bz remains in southward direction for approx. eight hours and then turned northward again and reached a normal value at ~ 0900 hrs UT on March 24, 2023. The rapid decline in IMF-Bz triggered the main phase of geomagnetic disturbance. The rapid decrease (increase) in IMF-Bz and the ensuing under-shielding (over-shielding) condition resulted in an eastward (westward) PPEF during the daytime and westward (eastward) at night. This phenomenon generates upward (downward) and downward (upward) vertical plasma movements in the equatorial ionosphere and low-latitude regions, respectively (Jain et al., 2024 and references therein).

From Fig. 1(d), it can be observed that the main phase onset (MPO) occurred at ~ 0800 UT on March 23, 2023. Dst reached its minimum value of -163 nT at 0315 UT on the subsequent day (March 24, 2023). It recovered its normal value of ~ 2000 UT on March 25, 2023. During this strong geomagnetic storm, variations in VTEC and $dVTEC$ are shown in Fig. 1(e) and Fig 1(f), respectively. On March 23, 2023, at 2030 UT approx. -50% deviation in VTEC was observed during the main phase of the storm. This may be due to the northward turning of IMF-Bz ~ 1600 UT and there by penetration of the westward electric field in the region. On March 24, 2023 $\sim +38$ % deviation in VTEC was observed during the recovery phase of the storm (~ 0500 UT). This may be attributed to the ionospheric disturbance dynamo effect in the region. After 0500 UT on March 24, 2023, the whole-day TECU was suppressed during the recovery phase and -75 % deviation in VTEC was observed at ~ 1500 UT. This may be attributed to thermospheric neutral composition changes in this region due to the Joule heating effect at auroral latitudes, which generates long-lived electric field disturbances at mid and low latitudes. The VTEC declined, from the normal peak of ~ 120 TECU, (~ 1000 UT) on March 21, 2023 to 50 TECU ($\Delta = -70$ TECU) at ~ 1000 UT on March 23, 2023 at Bhopal in Fig. 1(e).

This suppression is similar to the observations reported by several researchers for the equatorial and EIA region (Bagia et al., 2009; Chakaraborty et al., 2015; Choudhary et al., 2024; Jain et al., 2010; Shreedevi and Choudhary, 2017; Jain et al., 2024). Recently Rajana et al., 2023 conducted study for two stations KLEF (16.44° N, 80.62° E, GMLAT, 8.03° N) and HYDE (17.42° N, 78.55° E, GMLAT, 9.15° N) and concluded that $dVTEC$ declines in the range of 50-60 TECU, while for the low-latitude station IISC (13.02° N, 77.57° E, GMLAT, 4.86° N) it showed a $dVTEC$ of around 20 TECU for the same storm occurrence on March 22-23, 2023. These reductions in TEC indicate a significant negative ionospheric storm effect. Our results are similar and support the result reported by Rajana et al. (2024). Global Ultraviolet Imager (GUVI) onboard the Thermospheric-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite observes the column-integrated oxygen to molecular nitrogen ratio (O/N₂) (<https://guvitimed.jhuapl.edu/>). The daytime O/N₂ measurements were assimilated in the research to elucidate the response of ionospheric F-layer electron density variations. Fig. 2 presents the TIMED/GUVI images from March 22, 2023, to March 25, 2023, depicting the map of the



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[O/N₂] ratio, with values denoted by different colors. The approximate location of the receiver is indicated by the red arrow. As illustrated in Fig. 2, it is observed that on March 22, 23, and 24, 2023, no color is visible in the region of interest, potentially due to inadequate data recording. However, on March 25, 2023, a suppression in the region (~0.8-0.9) is clearly discernible in green. The suppression in VTEC from March 23, 2023, to March 25, 2023, is attributed to thermospheric neutral composition changes induced by the Joule heating effect at auroral latitudes, which generates long-lived electric field disturbances at mid and low latitudes.

Storm on April 23, 2023

An extremely active solar region emitted a halo Coronal Mass Ejection (CME) that reached Earth's vicinity, subsequently causing a severe geomagnetic storm on April 23-24. The effect of this geomagnetic storm is shown in Figure-3 for the period April 21-25, 2023. The solar wind (proton) speed (V_p), proton density (N_p), Dst, and IMF Bz are shown in Figure-3 (a-d). The vertical total electron content (VTEC) and percentage deviation of VTEC are given in Figure 1 (e-f), respectively. Figure 3(a) illustrates that the solar wind speed (V_p) reached its minimum value of 372 km/s at 0213UT on April 21, 2023. The value remained approximately constant from April 21, 2023 until 1805 UT on April 23, 2023. Subsequently, the solar wind speed began to increase gradually, reaching its maximum value of 711km/s at 2108 UT. Thereafter, it decreased gradually, and the solar wind speed stabilized at 524 km/s during the recovery phase of the storm. Fig. 3(b) illustrates the solar wind proton density. Its minimum value was 2.2 cm^{-3} at 0200 UT on April 21, 2023, after which it began to increase gradually, reaching 7.9 cm^{-3} at 1400 UT on April 21, 2023, before gradually decreasing. Subsequently, it remained constant from April 21, 2023 at 1600 UT to April 23, 2023 at 0800 UT. Following this period, distinct peaks were observed in the solar wind density. The first peak was recorded on April 23, 2023, with a value of 18.9 cm^{-3} at 2000 UT, while the second was observed on April 24, 2023, with a value of 14.1 cm^{-3} at 2400 UT. These two peaks occurred during the main phase of the storm. Variations in IMF Bz are depicted in Fig 3(c). On April 23, 2023, it exhibited initial fluctuations, moving southward before transitioning northward. Subsequently, it shifted slightly southward, reaching a value of -21 nT at 2000 UT, before turning strongly northward with a value of 12.1 nT at 2305 UT on April 23, 2023. Following this, it again shifted slightly southward, then northward, before experiencing a sudden southward drop. It reached its lowest value of approximately -32.4 nT at approximately 0305 UT on April 24, 2023, and attained its highest value of 22.5 nT at 1710 UT on April 24, 2023. It subsequently turned southward again and returned to its normal value on April 25, 2023.

The value of Dst remained approximately constant from April 21, 2023, at 0100 UT to April 23, 2023, at 0908 UT. The Dst value began to decline gradually from approximately 1600 UT on April 23, 2023, subsequently reaching a value of -163 nT at 2210 UT on April 23, 2023. Following a slight increase, it gradually decreased to the minimum Dst value of -213 nT at approximately 0605 UT on April 24, 2023. Subsequently, the recovery phase commenced, and the Dst value returned to its normal level on April 25, 2023, as illustrated in Fig. 3(d).

The variation in VTEC and percentage deviation in VTEC (d VTEC) are shown in Fig 3(e) and Fig 3(f) respectively. The VTEC peaks occur during April 21-23, 2023 at 1000 UT (~110 TECU) was slightly suppressed on April 24, 2023 (1000UT) on the storm day Fig 1(e). In addition, +28% deviation in VTEC was observed at ~ 0300 UT, which may be attributed to the prompt penetration of the electric field, aligning with the rapid decrease in IMF-Bz (-32.4 nT). Afterwards it drops again and the whole day VTEC was suppressed on April 24, 2023. This may be attributed to the thermospheric neutral composition changes and supported by the reduction in O/N₂ ratio in this region (refer Fig. 4). Our results for storm occurred on April 23, 2023 are agrees with the result reported by Rajana et al., 2024 for multiple stations, which falls in EIA region, Figure 4 shows the TIMED/GUVI images from April 22, 2023, to April 25, 2023, which shows the map of the [O/N₂] ratio, whose values are marked by different colors. The approx. location of the receiver is indicated by the red arrow. Suppression in the [O/N₂] ratio (0.7–0.8) is clearly visible on the day of the storm of April 23, 2023, as compared to April 22, 2023 (~0.8–0.9) and April 24, 2023 (~0.9–1.0). A similar suppression in the [O/N₂] ratio was found on April 25, 2023 (~0.7–0.8). Comparable findings were documented by Bagia et al. (2009) and Tiwari et al. (2011) regarding the geomagnetic storm that occurred in August. Using GPS-VTEC. Their research noted an increase in the O/N₂ ratio on August 24 and a decrease on August 25, based on TIMED/GUVI images. Recently, similar results were reported by Jain et al. (2024) for May 10-11, 2024 severe geomagnetic storm. The electron loss at the F2 peak was influenced by recombination/attachment with N₂; as N₂ density decreased



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(increased), electron density increased (decreased), resulting in a positive (negative) storm effect. Suppression in VTEC from April 23, 2023 to April 25, 2023, is attributed to thermospheric neutral composition changes by joule heating effect at auroral latitudes that generates long lived electric field disturbances at mid and low latitudes

Comparison with IRI-2020

We compare the observed GPS-VTEC with the TEC obtained from the IRI-2020 model for the March 23-24, 2023 and April 23-24, 2023 geomagnetic storms, and our results are presented in Fig. 5 and 6 respectively. In these figures, GPS-VTEC is depicted in blue, while IRI-TEC is represented in magenta. As illustrated in Fig. 5, the IRI-TEC exhibited close agreement with observed GPS-VTEC during the initial and main phases of the storm occurred on March 23. On March 21, 22, 24, and 25, 2023 IRI-TEC underestimated the observed GPS-VTEC values by approximately 38, 39, 40, and 20 TECU, respectively. Fig. 6 clearly indicate that the IRI-TEC underestimated GPS-VTEC during the all phases of the storm occurred on April 23, 2023.

CONCLUSION

In the present study, we investigated the ionospheric response to two strong geomagnetic storms that occurred during the ascending phase of 25th solar cycle on March 23-24, 2023 and April 23-24, 2023 over Bhopal and near the crest of the equatorial anomaly region. Prompt penetration electric fields (PPEFs) originating from under-shielding and over-shielding conditions demonstrated enhancement and suppression in vertical total electron content (VTEC) during the recovery phase for both storms. The suppression in VTEC during the recovery phase of the storm is attributed to the combined effect of thermospheric composition changes in this region, which is consistent with observations reported by several researchers for the equatorial and equatorial ionization anomaly (EIA) region (Bagia et al., 2009; Chakraborty et al., 2015; Choudhary et al., 2024; Jain et al., 2010; Shreedevi and Choudhary, 2017; Rajana et al., 2024). We also evaluated the performance of IRI-2020 for these strong geomagnetic storms. The results are summarized as follows:

- The March 23-24, 2023 and April 23-24, 2023 strong geomagnetic storms produced both positive and negative impacts on the VTEC at Bhopal.
- -76% deviation in VTEC during the main phase of the storm may attributed to the westward PPEFs and thermospheric neutral composition changes at 1533 UT on March 23, 2023 at Bhopal.
- A positive impact with a +38% deviation in VTEC was observed at approximately 0415 UT on March 24, 2023, which may be attributed to the presence of ionospheric disturbance dynamo effect in the region.
- A positive impact with a +28% deviation in VTEC was observed at approximately 0300 UT on April 24, 2023, attributed to PPEFs, whereas a negative impact of approximately -74% deviation in VTEC was observed at 1705 UT on April 24, 2023, and can be attributed to thermospheric neutral composition changes.
- Both the storms occurred on March 23-24, 2023 and April 23-24, 2023, shows positive deviations in the local morning hours while negative deviations were evident in the evening hours.
- IRI-TEC aligned well with GPS-VTEC during the storms occurred on March 23, 2023. However, it underestimates GPS-VTEC on the remaining days of both storms.

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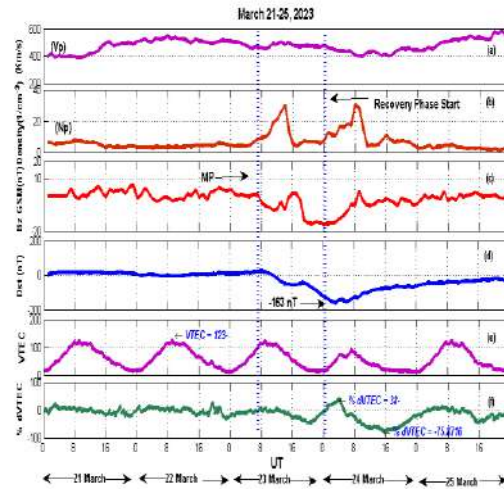


Figure 1- Variation of: (a) Solar wind (proton) speed V_p ; (b) proton density N_p ; (c) IMF B_z ; (d) Dst and (e) Vertical total electron content of VTEC (f) dVTEC during 21-25 March 2023.

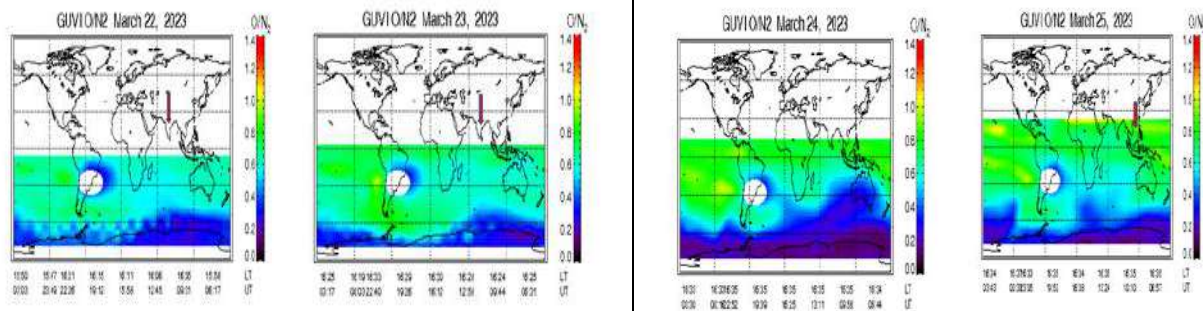


Figure 2: TIMED/GUVI image showing the thermospheric O/N₂ ratio during geomagnetic events on March 22, 23, 24, and 25, 2023.

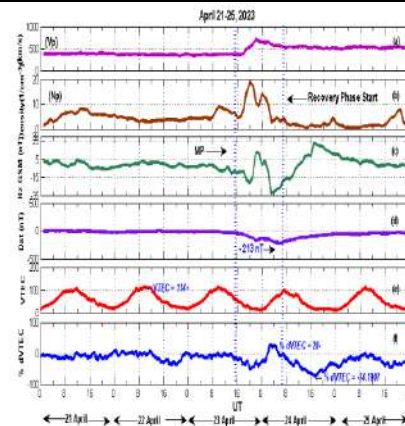


Figure 3- Variation of: (a) Solar wind (proton) speed V_p ; (b) proton density N_p ; (c) IMF B_z ; (d) Dst; (e) Vertical total electron content of VTEC; and (f) dVTEC, during 21-25 April 2023.





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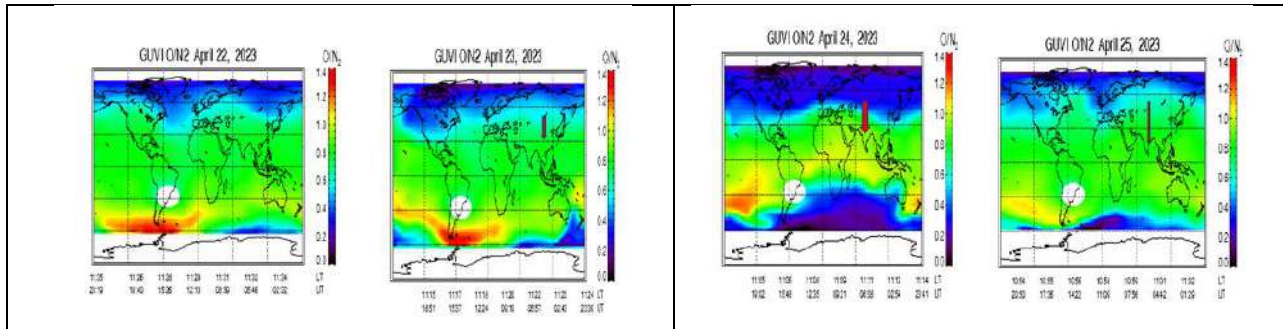


Figure 4: TIMED/GUVI image showing the thermospheric O/N₂ ratio during geomagnetic events on April 22, 23, 24, and 25, 2023.

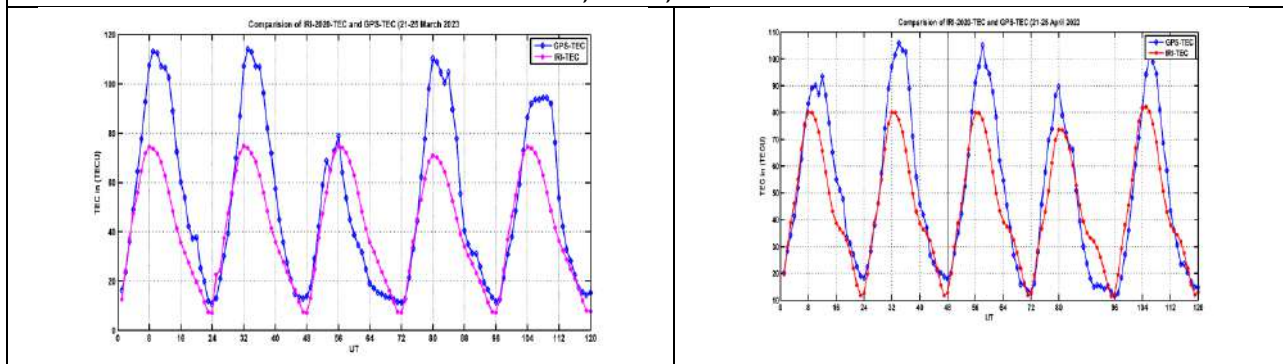


Figure 5. Comparison of observed GPS-VTEC with IRI-2020 TEC for the period from March 21-25, 2023.

Figure 6. Comparison of observed GPS-VTEC with IRI-2020 TEC for the period from April 21-25, 2023.





Hydrochemical Evaluation of Groundwater from Basaltic Terrain in Aundha Nagnath Tehsil of Maharashtra through WQI and GIS Approach

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ABSTRACT

In the phase of urban growth and industrialization, groundwater resource is utmost natural resource used widely in various region from rural to semi-urban and urban area for irrigation and drinking purpose. In Aundha Nagnath tehsil, majority of area covered by rural settlements; hence, quality of groundwater is meticulously accompanying with health of this rural inhabitants. Therefore, detailed hydrochemical investigation has been carried out along with its suitability for drinking and irrigation uses. On the basis of geomorphology, geology, LULC etc., a total one hundred and twenty (120) representative water samples were collected from study region during pre-monsoon (PRM) and post-monsoon (POM) periods of year 2023. The major ions including cations and anions were analyzed by standard procedures of American Public Health Association (APHA). Analytical results of groundwater samples were compared with standard guidelines given by World Health Organization (WHO, 2017) for drinking use. It is observed that water quality parameters like pH, magnesium (Mg), sodium (Na), calcium (Ca), sulphate (SO_4), chloride (Cl) are within allowable limit, excepts a few parameters like electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS), potassium (K), nitrate (NO_3) and bicarbonate (HCO_3) exceed the permissible limit (PL) of the WHO from PRM and POM seasons. The groundwater quality is mainly influenced by both anthropogenic and geogenic inputs. Water Quality Index (WQI) has been used to examined groundwater quality of drinking purpose and results signify that more than half of the area shows poor water quality for drinking in PRM and POM. The United States Soil Laboratory Staff's (USSL's) proposed a method for identification of groundwater quality for irrigation suitability and both PRM and POM results from present study depicts that low sodium and moderate to high salinity hazards.

Keywords: Groundwater, Hydrochemistry, Basaltic terrain, Irrigation, WQI, GIS





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INTRODUCTION

One of the basic and vital resource for living things in the world is groundwater. It is routine for drinking, agricultural, industrial and domestic purpose worldwide (Wagh et al. 2016). Major reserves of freshwater on the earth are occur as groundwater, which has been contributory approximate 100-times more water than numerous freshwater bodies like ponds, streams and lakes (Kumar et al. 2005). Now a days groundwater is a main growing reserve for consumption for all living being. Moreover, groundwater occurred in subsurface region which is stored in the rock openings. The annually usable surface water and subsurface water resources of India are predictable as 396 km³ and 690 km³ per year respectively (Dhingra et al. 2021). The groundwater moves through aquifer material, ionic constituents are dissolved in groundwater as of the minerals and rocks with which the water has reacted, either precipitating or dissolving (Zhou et al. 2000). In central India, particularly in Maharashtra Deccan volcanic provinces aquifers are the important source of subsurface water (Pawar et al, 2008). The groundwater travels through pore spaces and follow an easiest path within rocks material and it responds to mineral that dissolve from the rocks during the course of migration (Amadi et al. 2012; Boateng et al. 2016). Geogenic factors like lithology of any region plays a dynamic role to regulates geochemistry of groundwater and it signify the rock domain impact on water quality (Wagh et al. 2020). In India, rise in the groundwater demand owed to fast rising inhabitants, faster step of industrial expansion and development (Yisa and Tijani, 2010). The groundwater appropriateness for irrigation and drinking is significantly based on the concentration of major ions existing in the groundwater (Wagh et al. 2016). The groundwater deterioration is due to fast rising expansion and industrialization universally and due to overexploitation (Wagh et al. 2019a). Understanding groundwater chemistry is the critical fundament for mechanism analysis and quality evolution (Gaikwad et al. 2019; 2020b, Yunhui Zhang et al. 2021).

The study area is very significant in groundwater quality point of view and it needs to understand the geochemistry of groundwater for any further involvements if desirable. The worsening of groundwater is due to fast growing expansion and industrial development in the world (Gaikwad et al. 2020a). Hydrochemical investigation of water quality parameters like pH, EC, TDS, TH, HCO₃, major anions like Cl, NO₃, SO₄ and major cations like K, Ca, Na and Mg are essential for better understanding of overall superiority of groundwater from the study region. WQI has been assigned by Horton (1965) to regulate the excellence for drinking water in an index scale. It helpful for classification of drinking water excellence in an easiest way on scale of excellent to poor and its convenient for users in a particular area for good management of water resources. Many investigators have used this method from different locations worldwide for better classification of water quality which helps to end user easily. (Sethy et al., 2017; Trikoilidou et al., 2017; Alhadithi, 2018; Wagh et al., 2019b; Kadam et al., 2019a). The groundwater has been increasingly advanced as a backbone of India's drinking and agricultural water safety with its excellence and its contribution practically 62% in agriculture, 50% in urban water supply and 85% in rural water supply (CGWB, 2022). Based on SAR (Sodium Adsorption Ratio) and EC (Electrical Conductivity) values of the groundwater, proposed a diagram to ascertained the aptness of waters for agricultural persistence by USSLS's. USSSL diagram is the representation of water eminence for irrigation suitability by different classes of sodium and salinity hazard. Hence, the present research has been performed in the Aundha Nagnath region to study the hydrochemical evaluation through WQI and GIS with the main objectives of 1) to study the hydrochemical evaluation of major ions from pre- and post-monsoon seasons, 2) to ascertain the geological or anthropogenic influences through WQI and USSSL techniques, 3) to demarcate the polluted groundwater zones with the help of GIS tools.

Study area and geology

The Aundha (Nagnath) tehsil is located 19° 40' to 19° 71' N latitude and 76° 86' to 77° 24' E longitude and covered under Survey of India (SOI) toposheet numbers 56A/11, 12; 56A/14, 15, 16 and 56E/2, 3, 4 on the 1:50,000 scale (Fig.1). It is a part of Hingoli district and covers an area of approximately 813.17 km². Sidheshwar dam is one of the water reservoirs which is constructed on Purna river. The river Godavari, Purna, Asna, Kayadhu are the main river basin which is associated to drainage network of dendritic to sub dendritic in the study region (Sahu et al. 2020). Physiographically terrain exhibits the elevated mountain of Ajanta hill ranges with Hingoli Plateau of moderate to low



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towards south slope and elevation ranges from 561m to 304m above mean sea level (AMSL). Climatic conditions are dry except during southwest monsoon and annual precipitation of approximately 750 to 900 mm (GSDA, 2001). The range temperature is varying from 12.7 °C to 42°C in winter and summer seasons; however, hot and dry summers are more extreme than winters (CGWB, 2013). Soils of the study area derived from the parental rock Deccan basalt. The area under investigation is a part of the Deccan Trap with diverse lithology is a part of Deccan Trap Super group (Table 1). The litho units in the area include Deccan Trap Super group of Upper Cretaceous to Palaeocene age and inland river valley of alluvial sediments of quaternary age. The three main geological formations from the study region are Buldhana, Chikhli and Ajanta. The younger formation is Buldhana followed by Chikhli and Ajanta. It is consisting of three 'aa' flows in study area region. These lava flows are light grey, sparsely to moderately porphyritic with ropy surface. The Chikhli formation is comprising of one mixed flow with large aerial extent and is a rhythmically layered sequence of compound 'pahoe' and 'aa' units, while; Ajanta formation Comprises of three lava flows from study region are of mixed nature. These are rhythmically layered sequence of 'pahoe' and 'aa' flows where the upper part is vesicular and basal part with pipes and amygdules. The alluvium in the study area is of Quaternary age with dark to grey clay, silt, sand and gravel in nature (Fig. 1), (Table 1).

MATERIAL AND METHODS

In this study, a total number of 120 representative water samples were collected from pre-monsoon (PRM) and post-monsoon (POM) seasons (May 2023 and December 2023) from bore well (BW), dug well (DW), hand pump (HP) and surface water (SW) from the different locations with considering settlement, drainage pattern, geomorphology, geology etc. Out of 60 samples, 29 samples are from DW, 19 samples of BW, 11 samples of HP and 1 sample is SW i.e., Shiddheshwar Dam (Fig.1). Prior to water sample collection, one litre pre-sterile plastic bottles of poly-ethylene material were used. The sample bottles were labelled and sealed properly and brought to the laboratory for further analysis of physicochemical parameters. The physico-chemical analysis was carried out with standard analytical protocols of American Public Health Association (APHA, 2016). The location coordinates were recorded by Garmin eTrex 10 GPS for preparation of sampling location map. The parameters such as pH, EC and TDS were measured in field by Aquaread AP-700 and Multi-Parameter PCS Tester 35. Further, titrimetric method was used to calculate TH, Ca^{2+} , Cl^- and HCO_3^- . SO_4^{2-} and NO_3^- concentration was analysed on spectrophotometer (Shimadzu UV-1800). Na^+ and K^+ were determined using Systronics 108 flame photometer. For analytical precision, charge balance error (CBE) is considered and found within $\pm 10\%$. WQI method is used to expressed the water quality as excellent, good, poor, very poor and unfit for drinking based on its numerical values. Also, spatial distribution maps were prepared for better understanding of poor water quality zones using Arc GIS 10.8 v software. USSL is well design diagram used for irrigation suitability based on SAR and EC values.

RESULTS AND DISCUSSION

Hydrochemical investigation

Generally, the pH, EC, TH and TDS are both anthropogenically and lithologically affected in the various study area. The Ca^{2+} , Mg^{2+} , Na^+ and K^+ cations are dominated through geogenic (basalt) and agricultural sources; while, the Cl^- , SO_4^{2-} and NO_3^- ions derived mainly from uses of chemical fertilizers, pesticides and man-made activities (Wagh et al. 2019a, Farid et al. 2023). pH is on scale, EC in $\mu\text{S}/\text{cm}$ and remaining all parameters are in mg/l (PL: Permissible Limit, DL : Desirable Limit) Hydrochemical analysis of both PRM and POM seasons illustrated in table 2, reveals that pH values varying from 6.35-8.5 in PRM and 5.9-8.3 in POM with an average value of 7.64 and 6.9 respectively. According to WHO2017 drinking standards majority of samples from both the monsoon are below PL. pH of groundwater shows acidic to alkaline in nature is owed to basaltic terrain (Pawar et al. 2008). EC values vary from 313-2370 (PRM) and 365-1729 (POM) with its average values of 847.13 and 790. The TDS shows below PL with mean values of 600.25 and 561.83 in PRM and POM seasons. From the result of TH, it specifies that water is hard for drinking use and may owed to Ca and Mg rich natural factors like basaltic rocks contributing in geochemistry (Wagh et al. 2019a, Deshpande, 1998). Cationic trend is in ascending order of $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$ (PRM) and $\text{Mg} > \text{Na} > \text{Ca} > \text{K}$ (POM)





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with majority of samples is below permitted limit except a few of K samples and signifying those high values of Ca and Mg are due to basalt terrain reveals the geogenic inputs from olivine, plagioclase, biotite etc minerals bearing lithology (Pawar et al. 2008). The tendency of anions is in increasing trend of $\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{NO}_3^-$ in PRM and POM. This tendency evidently signifying contribution of anthropogenic contamination of Cl^- , SO_4^{2-} and NO_3^- in groundwater (Wagh et al. 2016, 2020; Gaikwad et al. 2020b; Patil et al. 2024). As compared to WHO limits, geochemistry of major ions specifies that overall groundwater quality from study area is moderately suitable for drinking purpose. According to Davies and DeWiest classification (1966)(table 3), 45% (PRM) and 46.67% (POM) samples falls in desirable for drinking category. The remaining 46.66% (PRM) and 53.33% (POM) samples and 8.34% (PRM) and 5% (POM) samples are permissible for drinking which is generally freshwater and useful for irrigation (freshwater to brackish water) respectively. Aquifer bodies with long dwell times, weathering parent rock components, salts from the soil and wastewater, all contribute to the groundwater elevated dissolved solids levels (Subramani et al. 2010; Nematollahi et al. 2016). In this area the main contributor of TDS concentration is weather basalts (Dimple et al. 2023). The classification based of EC values (Dar et al. 2011), permissible class represented 91.66% (PRM) and 96.66% (POM) samples and 8.34% and 3.34% from PRM and POM seasons, characterised as not-permissible class and these samples are influenced by salinity and human activities leads to more concentration. No one sample from study region shows hazardous class (table 4). Sawyer and Mc Carty classification (1967) is represented in table 5, which specifies that groundwater hardness based on different classes, 8.34% and 0% of samples from pre- and post-monsoon season shows soft water category; while, 43.33% (PRM) and 1.67% (POM) samples indicating moderately high class with range of 75-150 mg/l. It observed that 41.66% and 6.67% (PRM) and 41.67% and 56.66% (POM) samples fall under hard to very-hard water types respectively which is owed to presence of alkaline earth elements in the study area (Pawar et al. 2008).

Computation of Water Quality Index (WQI)

WQI is used widely to ascertain the water quality for beneficial use in any study region. The WQI has computed by considering various water quality variables like pH, EC, TDS, TH, cations (Ca, Mg, Na, K) and anions (Cl^- , NO_3^- , SO_4^{2-} , HCO_3^-). The WHO drinking water specification is used for computation of WQI. The weightage is assigned to each water quality variable by considering apparent hazard to water eminence. The assigned weights on degree of 1 to 5 scale by considering the relative importance in drinking and health risk potential (Table 6). Relative weights (Rwi) to water quality parameters are illustrated in table 6. Subsequent equation is used to calculate WQI;

$$\text{Rwi} = \text{Awi} / \sum \text{Aw} \quad \text{qi} = (\text{ci} / \text{si}) * 100 \quad \text{Sli} = \text{Rwi} * \text{qi} \quad \text{WQI} = \sum \text{Sli}$$

where, Rwi = relative weight, Awi are assigned weight of i^{th} parameters, qi = quality rating for i^{th} parameter, ci = content of i^{th} chemical parameter of water sample (mg/l), si = desirable standards for i^{th} parameter set by the WHO, Sli = sub-index of i^{th} parameter and WQI = Water Quality Index. Based on these stated methods, WQI for the groundwater of Aundha (Nagnath) tehsil has been calculated and values are represented in table 7. It is classified into five different classes, viz., class first indicate excellent type of water having class range of 0-50; class with range in between 50–100 represent as good water quality; value with 100–200 fall under poor category; very poor class of water type ranges from 200-300 and WQI values >300 signify as not fit for drinking (table 7). Its value range among 80.59-193.3 (PRM) and 72.06-301.61 (POM); although, overall water quality according to average values of area is poor in both PRM and POM (table 7) (Fig. 2). Table of categorization of water quality depicts that 11 and 18.34% samples and 16 and 26.67% samples fall under good water category in PRM and POM respectively. This area having a very few dense urbanization and industrialization, although; it is observed that 81.66% (PRM) and 71.66% samples (POM) characterize as poor water quality, which owed to the continued exhaustive consumption and agriculture may affects human health (Wagh et al. 2018, Howladar, 2018). Only 1.67% sample is unfit for drinking from POM (table 7). In general, overall water eminence from study region s exaggerate owed to water-rock contact and low hydraulic gradient (Varol and Davraz, 2015; Kumar and Mourya, 2023). Furthermore, water quality from POM has been undesirably pretentious from renewing water due to its soakings the salinities from domestic waste and agricultural field. Figure 2 is the well illustration for good type of water from numerous sampling locations in PRM and POM;



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whereas, more samples from poor type (PRM and POM) and one sample (POM)(sample number 18) come under unfit type, clearly represent in WQI spatial distribution maps and it represents that overall water quality for drinking purpose is poor (Fig. 2).

The United States Soil Laboratory Staff's (USSLS's, 1954)

Based on SAR and EC values of the ground water, a diagram has been proposed to ascertain the aptness of waters for persistence irrigation also known as USSL plot (Fig. 3). In this plot, the EC values are represented on log scale plot against SAR on the arithmetic scale is plotted. This diagram is divided into different classes such as a slow (C1), medium (C2), high (C3) and very high (C4) for EC (C= salinity hazards) and low (S1), medium (S2), high (S3) and very high (S4) for SAR (S= sodium hazards). Where, C and S with 1-4 values indicates different classes of agricultural suitability of groundwater. US Salinity Laboratory hazard diagram (USSL's) is created by associating sodium adsorption ratio (SAR) and electrical conductivity (EC). In this study it specifies that twenty-five (25) i.e. 41.67% groundwater samples of the study region fall in the category of C2–S1 groups (low sodium and medium salinity hazard), thirty-four (34) i.e. 56.66% samples are come under C3–S1 indicates that low sodium and high salinity hazard; while, only 1 sample (sample number 21) fall under C4–S1 i.e. 1.67% sample signify very high salinity and low sodium hazard (PRM). Moreover, in POM, 31 samples (51.66%) and 29 samples (48.34%) fall in C2–S1 and C3–S1 classes which indicating medium-high salinity and low sodium hazard (Fig. 3). High to very high sodium hazard represents excess usage of chemical fertilizers and pesticides (Wagh et al. 2018, Ahadi et al. 2019).

CONCLUSION

The hydrochemical evaluation coupled with WQI and GIS approach is summaries with succeeding conclusion; cation abundance is in ascending order of $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$ (PRM) and $\text{Mg} > \text{Na} > \text{Ca} > \text{K}$ (POM) and anionic tendency trend of $\text{HCO}_3 > \text{Cl} > \text{SO}_4 > \text{NO}_3$ in both PRM and POM. As from hydrochemical analysis result, water quality is acidic to slightly alkaline. Majority of parameters are within WHO limits; except, EC, TH, TDS, K, NO_3 and HCO_3 from both PRM and POM. Also, it specifies that overall groundwater quality is moderately desirable for drinking purpose after comparison with WHO drinking water guidelines. WQI specifies that only a few samples (18.34% and 26.67%) having good water quality; while, 81.66% and 71.66% samples showing poor water quality in PRM and POM seasons. Spatial variation map has been prepared and it indicates that only 1 sample (sample number 18) from POM shows unfit class for drinking. USSL salinity diagram represent that, 41.67% groundwater samples of the study region fall in the low sodium and medium salinity hazard, 56.66% samples are come under low sodium and high salinity hazard; while, only 1 (one) sample 1.67% (sample number 21) signify very high salinity and low sodium hazard in PRM. Furthermore, in POM, 51.66% and 48.34% samples fall in classes which indicating medium-high salinity and low sodium hazard. Nut shell, the overall water quality for drinking and agriculture is moderately suitable. Though, it is suggested that, in future water quality improvement methods are required with considering the natural as well as anthropogenic inputs. The results of this work will useful as baseline data to local administrative authorities and new researchers in hydrochemistry to develop a sustainable groundwater management strategy in the study area.

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Conflict of Interest

The authors declare that there is no conflict of interest in this paper.

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Table 1: Stratigraphic succession of the study area (DRM, GSI, 2019)

Litho-code	Lithology	Supergroup	Group	Formation	Age
Qal	Alluvium	-	-	-	Quaternary
dshb5 dshb4 dshc3	Basalt	Deccan Trap	Sahyadri	Buldhana	Upper Cretaceous to Palaeocene
dshc6	Basalt			Chikhli	
dsha5 dsha4 dsha3	Basalt			Ajanta	

Table 2: Statistical summary of hydrochemical analysis and comparison with WHO drinking limits

Parameter	WHO Limit (2017)	Pre-monsoon 2023					Post-monsoon 2023				
	DL-PL	Min.	Max.	Avg.	Sample % above DL	Sample % above PL	Min.	Max.	Avg.	Sample % above DL	Sample % above PL
pH	6.5-8.5	6.35	8.5	7.64	96.66	0	5.9	8.3	6.9	66.66	0
EC	500-1500	313	2370	847.13	83.33	8.34	365	1729	790	86.66	3.34
TDS	500-1500	223	1700	600.25	53.33	1.67	257	1210	561.83	58.33	0
TH	100-500	52	382	165.05	81.66	0	134	502	303.2	98.33	1.67
Ca	75-200	12.02	112	56.76	20	0	5.61	157.11	42.08	10	0
Mg	50-100	15	75	45.55	41.66	0	12.67	117.44	51.22	50	5
Na	200-600	10	89	47.38	0	0	7.8	195.8	42.36	0	0
K	10 -12	5	20	9.83	21.66	20	0.1	188.5	5.52	1.67	8.34
Cl	250-500	20	117	72.04	0	0	28.82	376.3	80.73	1.67	0
HCO ₃	200-500	130	690	438.25	58.33	35	120	485	273.92	83.33	0
SO ₄	200-250	18	90	50.88	0	0	10	77	44.28	0	0
NO ₃	45	15	57	39.15	40	40	9	61	25.65	1.67	1.67





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Table 3: Classification of groundwater based on TDS

Classification	Range	Number of samples		% of samples	
		PRM	POM	PRM	POM
Desirable for drinking	< 500	27	25	45	46.67
Permissible for drinking	500-1000	28	32	46.66	53.33
Useful for irrigation	1000-3000	5	3	8.34	5
Unfit for irrigation	> 3000	0	0	0	0

Table 4: Classification of groundwater based on EC

Classes	EC	Number of samples		% of samples	
		PRM	POM	PRM	POM
Permissible	< 1500	55	58	91.66	96.66
Not-permissible	1500-3000	5	2	8.34	3.34
Hazardous	3000	0	0	0	0

Table 5: Groundwater classification based on TH content

Classification	Range	Number of samples		% of samples	
		PRM	POM	PRM	POM
Soft	< 75	5	0	8.34	0
Moderately high	75-150	26	1	43.33	1.67
Hard	150-300	25	25	41.66	41.67
Very hard	>300	4	34	6.67	56.66

Table 6: Weightage assigned to each parameter and their relative weights

Parameter	Assigned Weight (Aw)	Relative Weight (Rw)	Drinking Standards (Si)
pH	4	0.11	6.5
EC	4	0.11	500
TDS	3	0.08	500
TH	4	0.11	100
Ca	3	0.08	75
Mg	4	0.11	50
Na	1	0.03	200
K	3	0.08	10
HCO ₃	4	0.11	200
Cl	2	0.06	250
SO ₄	1	0.03	200
NO ₃	3	0.08	45
Sum (Σ)	36	1.00	





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Table 7: Categorization of water quality based on WQI range

Range	Classification	PRM_2023		POM_2023	
		Total sample numbers	Sample %	Total sample numbers	Sample %
0-50	Excellent	0	0	0	0
50-100	Good	11	18.34	16	26.67
100-200	Poor	49	81.66	43	71.66
200-300	Very poor	0	0	0	0
>300	Unfit for drinking	0	0	1	1.67

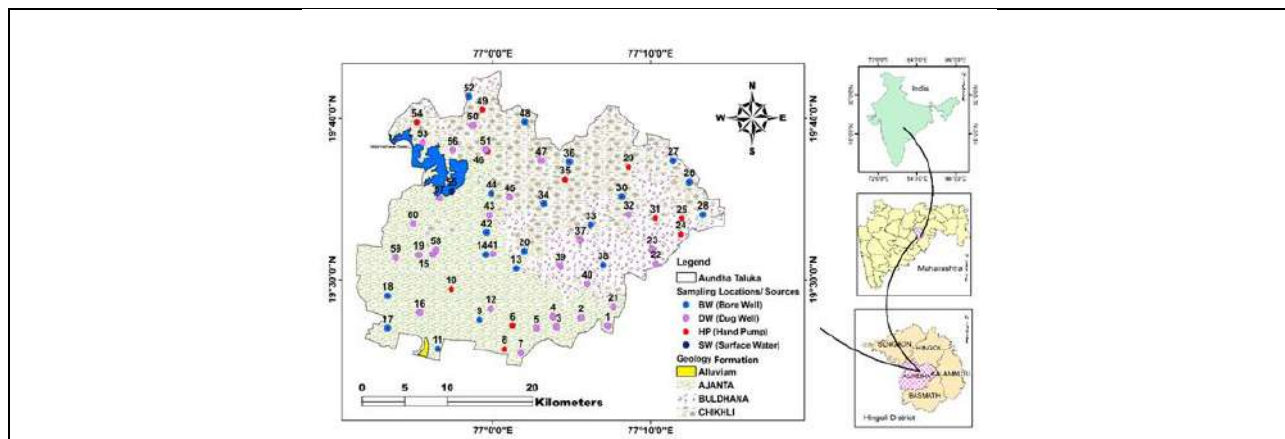


Fig. 1: Study area sampling Location with Geology

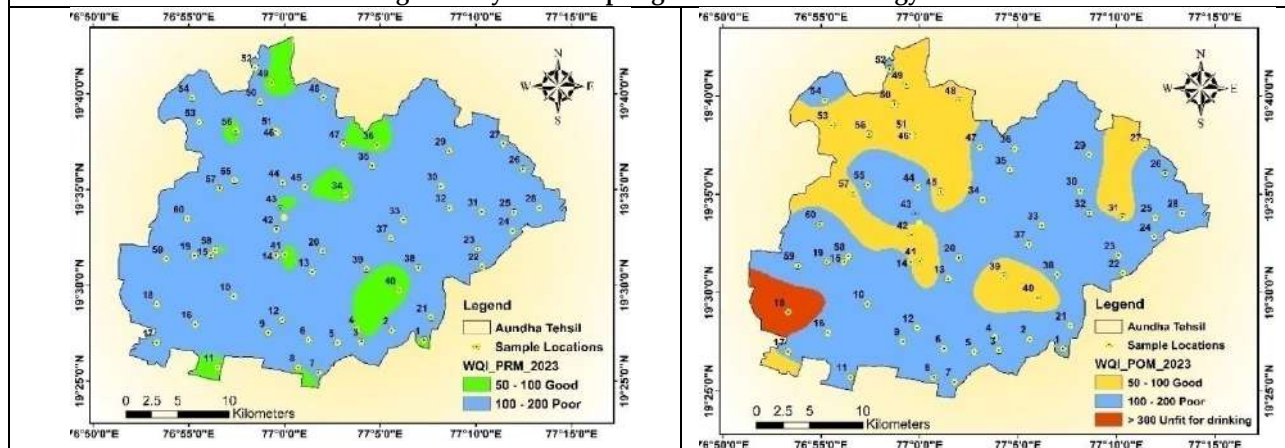


Fig. 2: Spatial variation of WQI from PRM and POM of the study area





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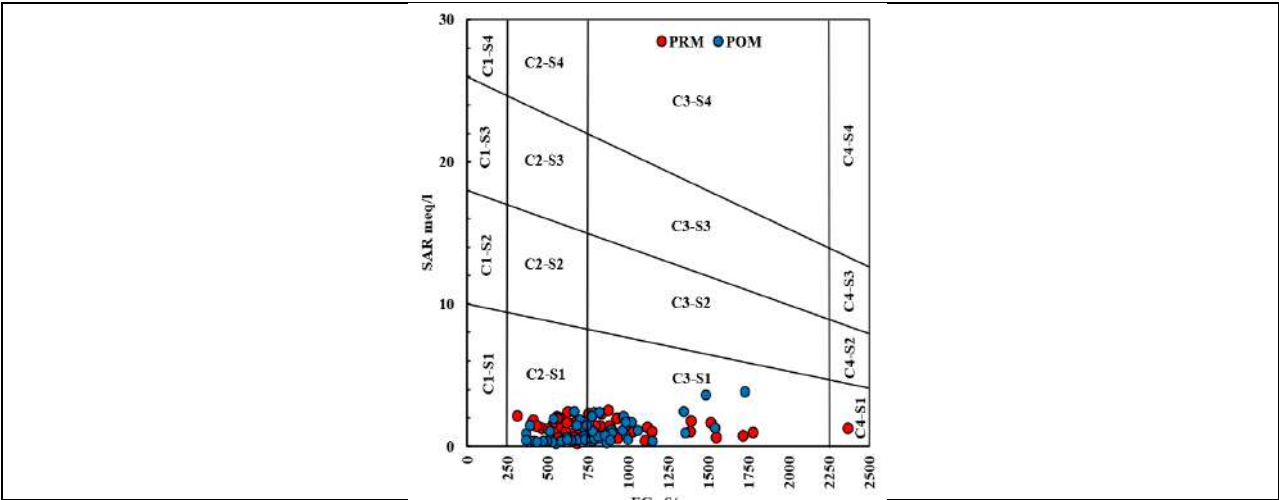


Fig. 3: USSL diagram for irrigation suitability





Intrusion Detection System using Spiking Neural Networks with Temporal Encoding and STDP Learning

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ABSTRACT

As the use of wireless devices continues to rise, the incidence of cyber-attacks has similarly escalated, making cyber security a global priority. Intrusion Detection Systems (IDS) play a pivotal role in safeguarding cyberspace by identifying malicious activities on the internet. While embedding machine learning (ML) algorithms into IDS has enhanced detection efficiency, there remains a need for more effective approaches for real-time monitoring and detection. In this context, we introduce Spiking Neural Networks (SNN) to detect temporal malicious attacks such as DDoS, brute force attacks, and SQL injection. Our approach also includes the classification of normal and malicious behavior, providing a robust solution for dynamic and real-time intrusion detection.

Keywords: Intrusion Detection System (IDS), Spiking Neural Networks (SNNs), temporal encoding, Spike-Timing-Dependent Plasticity (STDP), Winner-Take-All (WTA)





INTRODUCTION

In this era of wireless communication, the usage of the internet has grown to such an extent that people now depend on it for everything from basic grocery payments to high-level financial transactions. However, as internet dependency increases, the prevalence of cyber-attacks has also risen. Miscreants conduct cyber-attacks in various ways, such as password cracking, phishing, SQL injection, DDos, buffer overflow attacks, and IP spoofing. To address this growing threat, Intrusion Detection Systems (IDS) were introduced to detect and control such intrusions. Over time, different machine learning algorithms, such as Support Vector Machines (SVM), K-Nearest Neighbour (KNN), and Naïve Bayes, have been employed to improve the efficiency of IDS. These algorithms achieved accuracy rates of 97.77%, 93.33%, and 95.55%, respectively, in detecting intrusions [5]. However, when it comes to real-time prediction, IDS requires a more efficient approach than classical machine learning algorithms, which can be achieved through Spiking Neural Networks (SNNs). As SNNs are event-based processing systems, they can monitor and generate spikes in response to intrusions, enabling real-time prediction [9]. Additionally, SNNs are noise-tolerant and energy-efficient, making them ideal for modern IDS applications. This document will explore how SNNs are used in IDS to efficiently predict and detect intrusions.

LITERATURE SURVEY

IDS using SVM and Decision tree

The SVM classification system involves preprocessing the data by mapping symbolic features to numeric values and implementing scaling to address the varying resolutions and ranges in the data. The attribute data are scaled to fall within the range [-1, 1]. Attack names are then mapped to one of two classes: 0 for Normal and 1 for Attack. Features are ranked according to the score assigned by the Information Gain Ratio (IGR) measure. The k-means classifier is subsequently used to compute the detection rate (accuracy) for each subset of features. Initially, the set of features SS contains only the top-ranked feature. After each iteration, a new feature is added to the list SS based on the rank assigned by the IGR measure, one by one, as long as the accuracy of the selected subset does not decrease. When the accuracy drops, indicating potential model overfitting, the algorithm is stopped [1].

IDS using Navie Bayes

The researcher utilized the naïve Bayes classifier available in the WEKA (Waikato Environment for Knowledge Analysis) software. For testing, they employed both the full training set and a 10-fold cross-validation method. In 10-fold cross-validation, the dataset is randomly divided into 10 equal-sized, non-overlapping subsets. Each subset takes a turn as the test set, while the other nine subsets are used to train the classifier. The classifier's accuracy is then evaluated using the test set. This procedure is repeated 10 times to ensure that each subset acts as the test set exactly once. The overall accuracy is calculated as the average of the results across all iterations. This approach achieved a detection rate of 95%. [2].

IDS Using kNN

In this approach, once a training dataset representing normal system behavior is prepared, the k-Nearest Neighbors (kNN) method can be utilized for anomaly detection. The test audit data is analyzed to extract the sequence of system calls for each new process. These sequences are then converted into vectors using the same weighting technique as in the training phase. The similarity between the vector of the new process and each vector in the training dataset is computed using a specified formula. If the similarity score of any training process is exactly 1, indicating a perfect match in system call frequencies between the new and training processes, the new process is classified as normal immediately. If no perfect match exists, the similarity scores are ranked, and the k-nearest neighbors are identified. The average similarity score of these neighbors (i.e., the k closest matches) is then calculated. A predefined threshold is applied: the new process is classified as normal only if its average similarity score exceeds the threshold[3]. Here's a comparison of Intrusion Detection Systems (IDS) using SVM, KNN, and Naïve Bayes presented in a table format for clarity, which clearly shows that these ML algorithms are not enough efficient for real





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time performance and sensitivity to noise and it can be overcome by the proposed Intrusion detection system using SNN

PROPOSED METHODOLOGY

In this proposed methodology, we outline the design and operation of an Intrusion Detection System (IDS) using Spiking Neural Networks (SNNs), leveraging temporal encoding and Spike-Timing-Dependent Plasticity (STDP) learning [7] to analyze and classify network behavior. This approach enables the system to detect anomalous activity, such as password cracking attempts, by identifying deviations in temporal patterns of network traffic. The system begins at the input layer, where network traffic patterns, x_i , observed at time t_i , are processed using a temporal encoding function f_{encode} to generate spike trains $S(t)$ at specific spike times t_s . The temporal encoding process maps inter-event timing information $\Delta t = t_{i+1} - t_i$ into spikes, effectively capturing the temporal dynamics of the network traffic. Normal network behavior, characterized by steady and predictable activity, results in sparse spike generation, where the spike rate $\lambda_s(t)$ remains minimal, indicating the absence of anomalies. Conversely, intrusive behavior, such as repeated login attempts, generates spikes with higher frequency $\lambda_s(t) \gg \lambda_s^{\text{normal}}$ or shorter latencies $t_s \rightarrow 0$, reflecting abnormal activity. To ensure precision, synaptic thresholds θ_{syn} are defined to regulate spike generation, suppressing spikes when $\Delta t > \theta_{\text{syn}}$ and reducing noise. This approach ensures an efficient and precise mapping of network events into spike trains, distinguishing between normal and anomalous patterns in the network.

Spike-Timing-Dependent Plasticity (STDP) in the Hidden Layer

The encoded spike trains $S(t)$ generated by the input layer are transmitted to the hidden layer, where the Spiking Neural Network (SNN) employs **Spike-Timing-Dependent Plasticity (STDP)** as the learning mechanism [6] [7]. The STDP rule adjusts the synaptic weights w_{ij} between neurons dynamically, based on the relative timing of presynaptic and postsynaptic spikes. The change in synaptic weight, Δw_{ij} , is determined by the STDP update function

$$\Delta w_{ij} = \eta \cdot \exp(-|t_j - t_i| / \tau_{\text{STDP}})$$

Where Δw_{ij} change in synaptic weight between neuron i (presynaptic) and neuron j (postsynaptic), η is the Learning rate of SNN, t_j and t_i Spike times of the presynaptic and postsynaptic neurons, respectively, τ_{STDP} is time constant defining the sensitivity window for STDP.

For typical network traffic, the timing between spikes aligns with expected temporal patterns, causing synaptic weights w_{ij} to converge towards stable values. ie

$$\Delta w_{ij} \rightarrow 0, \text{ if } |t_j - t_i| > \tau_{\text{STDP}}$$

And for unusual network behavior, such as irregular timing or burst-like activity, the synaptic weights undergo significant adjustments. ie

$$\Delta w_{ij} \gg 0, \text{ for } |t_j - t_i| \ll \tau_{\text{STDP}}$$

This learning process autonomously identifies temporal correlations in network traffic.

Output Layer and Classification Using Winner-Take-All (WTA)

The output layer aggregates the spike patterns processed by the hidden layer and classifies network behavior as either normal or anomalous using the Winner-Take-All (WTA) mechanism [8]. This classification relies on the density, pathways, or timing of spikes received from the hidden layer. Each output neuron N_c corresponds to a specific class c , such as "normal" or "anomalous." The spike count C_c for each neuron is defined as

$$C_c = \sum_{k=1}^n S_k(t)$$

Where C_c is Spike count for class c , $S_k(t)$ is Spike activity from hidden layer neuron k at time t and n is total number of neurons in the hidden layer projecting to N_c . In the WTA mechanism, neurons in the output layer compete based on their spiking activity. The "winning" neuron is determined as

$$c_{\text{win}} = \arg \max_c C_c$$

Where c_{win} is the class of the neuron with the highest spike count. And finally the decision is based on the winning neuron.





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Behavior=Normal, $\left\{ \begin{array}{l} \text{if } C_{win} = \text{"normal"} \\ \text{Anomalous, if } C_{win} = \text{"anomalous"} \end{array} \right.$

Normal behavior is characterized by predictable and sparse spike patterns, leading to a lower C_c value for the neuron associated with the "anomalous" class. ie. $C_{normal} \gg C_{anomalous}$ and anomalous behavior is characterized by dense or irregular spike distributions, resulting in a higher C_c for the "anomalous" neuron, ie. $C_{anomalous} \gg C_{normal}$. The WTA mechanism ensures biologically plausible decision-making by suppressing the activity of all non-winning neurons [8] [10]. This competitive process highlights the most significant response to the observed spike patterns, enabling the efficient and accurate classification of network behavior.

Algorithm:

1. **Input Layer (Temporal Encoding):**
 - 1.1. Capture network traffic x_i at timestamps t_i .
 - 1.2. Encode x_i into spike trains $S(t)$ using temporal encoding.
 - 1.3. Apply synaptic limits to filter noise.
2. **Hidden Layer (STDP Learning):**
 - 2.1. Receive $S(t)$ from the input layer.
 - 2.2. Update synaptic weights using the STDP rule:
 $\Delta w_{ij} = \eta \cdot \exp\left(\frac{-(|t_j - t_i| - \tau_{STPL})}{\tau_{STPL}}\right) \cdot \tau_{STPL}$
 - 2.3. Strengthen pathways for normal patterns; adjust for anomalies.
3. **Output Layer (Classification):**
 - 3.1. Aggregate spikes from the hidden layer.
 - 3.2. Apply Winner-Take-All (WTA) mechanism:
 - Neuron with the highest spike count classifies traffic as "normal" or "anomalous."
4. **Decision:**
 - 4.1. Flag and log anomalous behavior.
 - 4.2. Adapt the system by updating weights based on new traffic patterns.
5. **Repeat:**
 Continuously process new traffic data for real-time detection.

RESULT

The classification system effectively differentiates between normal and anomalous network traffic by leveraging spike-timing-dependent plasticity (STDP) in the hidden layer and the Winner-Take-All (WTA) mechanism in the output layer. As shown in the spike activity plot, normal traffic is characterized by sparse and predictable spike patterns, while anomalous traffic generates dense and irregular spike patterns, reflecting deviations from typical network behavior (fig 1). The **WTA decision** process accurately classifies the observed network traffic into two categories: "normal" and "anomalous." The spike counts for the "anomalous" class were consistently higher, indicating the system's ability to highlight deviations in traffic patterns. The output classification was determined by the neuron with the highest spike count, confirming the system's effectiveness in distinguishing between these two behaviors (fig 2). To further assess the system's performance, the Receiver Operating Characteristic (ROC) curve was utilized to evaluate the trade-off between the True Positive Rate (TPR) and False Positive Rate (FPR). The ROC curve demonstrated the system's robust ability to detect anomalous traffic while minimizing false alarms. The Area Under the Curve (AUC) metric was calculated, yielding a value close to 1, signifying that the system achieves high accuracy in distinguishing between normal and anomalous behavior (fig 3). These results confirm that the system can





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autonomously detect network anomalies based on temporal patterns of spikes, providing an efficient, biologically inspired approach to network traffic classification.

CONCLUSION

In conclusion, this IDS leverages the unique properties of SNNs to bridge the gap between biological inspiration and practical applications in network security. By capturing temporal dynamics and adapting synaptic weights to learn network behaviors, it ensures robust and efficient detection of intrusions, enhancing the security of modern digital systems. Future work could involve fine-tuning the temporal encoding granularity, calibrating STDP parameters, and integrating advanced classification methods to further improve accuracy and efficiency.

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Table 1 comparison of Intrusion Detection Systems (IDS) using SVM, KNN, and Naïve Bayes

Aspect	Support Vector Machine (SVM)	K-Nearest Neighbor (KNN)	Naïve Bayes
Approach	Supervised learning with a hyperplane to separate classes	Instance-based learning using distance metrics	Probabilistic classification using Bayes' theorem
Accuracy	High (e.g., 97.77%)	Moderate to high (e.g., 93.33%)	High (e.g., 95.55%)
Complexity	Computationally expensive, especially during training	Computationally expensive during classification	Low computational complexity
Handling High Dimensions	Effective with kernel methods	Can handle, but performance decreases with many dimensions	Performs poorly with too many dimensions
Scalability	Limited scalability for very large datasets	Struggles with large datasets due to storage and computation	High scalability due to its simplicity





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Sensitivity to Noise	Sensitive to noise, especially in overlapping class boundaries	Sensitive to noise, as it directly impacts nearest neighbors	Less sensitive due to probabilistic nature
Real-Time Performance	Moderate, as it requires significant training but fast inference	Poor, due to the need to calculate distances for classification	Good, due to its low computation requirements

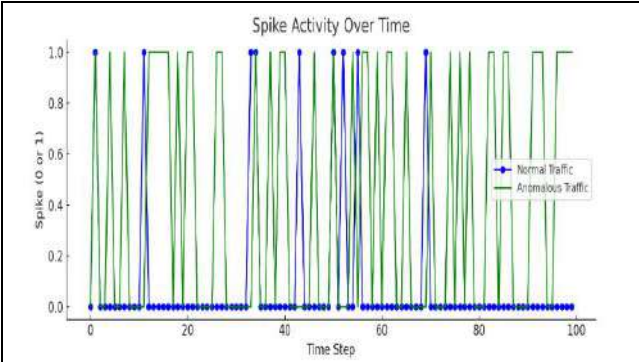


Fig 1.Temporal Spike Patterns for Normal and Anomalous Traffic

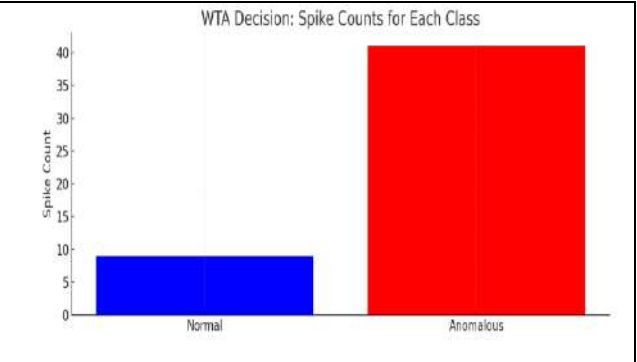


Fig 2. WTA Decision: Spike Counts for Each Class Graph

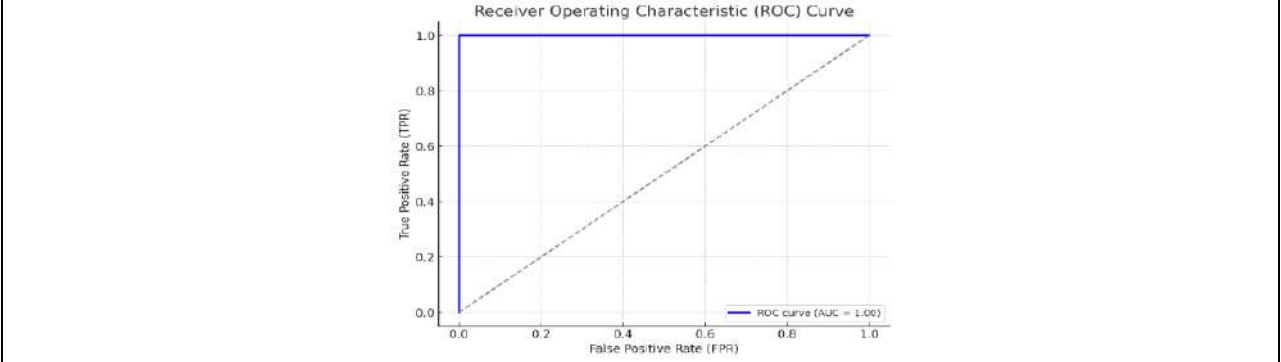


Fig 3. Receiver Operating characteristic (ROC) curve





Screening Models and Phytoconstituents for Antidepressant Activity: A Comprehensive Overview

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ABSTRACT

This review explores the antidepressant potential of various phytoconstituents, highlighting their mechanisms of action and therapeutic benefits. Natural compounds such as quercetin, harmine, ginsenosides, linalool, resveratrol, essential oils (lavender and bergamot), and tannic acid have demonstrated significant promise in regulating mood and reducing symptoms of depression and anxiety. These phytoconstituents act through diverse pathways, including modulation of neurotransmitters like serotonin, regulation of the hypothalamic-pituitary-adrenal (HPA) axis, and neuroprotection. While the evidence suggests these compounds may serve as effective natural alternatives or complements to conventional antidepressant treatments, further clinical research is necessary to confirm their efficacy and safety. This review emphasizes the growing importance of phytoconstituents in mental health management and their potential role in developing novel, plant-based antidepressant therapies. Antidepressant screening models are critical for discovering and developing new depression-specific treatment medicines. This review provides a thorough overview of current methodology, which include in vivo and vitro models such as forced swim test, tail suspension test, cell-based and receptor binding assays, high-throughput screening (HTS) technologies, and in silico computational approaches. Furthermore, machine learning (ML) and artificial intelligence (AI), have emerged as effective tools for predicting medication efficacy, pharmacokinetics, and probable side effects. Future directions, including biomarker identification, computational models, and personalized approaches, aim to improve the predictability and efficiency of antidepressant discovery.



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Keywords: Antidepressant screening, cell-based assays, receptor binding assays, behaviour test, high-throughput screening, in silico screening, artificial intelligence, Phytoconstituents.

INTRODUCTION

Depression is a life-threatening condition that affects hundreds of millions. It can happen at any age, from early childhood to late life. Depression can lead to a loss of hope, ambition, and even the desire to live, causing significant societal costs.[1] Despite breakthroughs in depression treatment with SSRIs and SNRIs, there are still unmet clinical needs regarding efficacy and side effects. These demands include efficacy in treatment-resistant patients, improved onset, and reduced side effects such as emesis or sexual dysfunction. Several combination medicines and novel targets have been developed to address these demands and potentially improve outcomes in multiple areas. The aims and approaches used vary greatly.[2] Antidepressant screening models are pivotal in the ongoing quest to identify effective treatments for Major Depressive Disorder (MDD), which is the leading source of disability worldwide. The intricate nature of depression presents significant challenges in drug development, necessitating diverse methodologies to ensure that new compound candidates are assessed accurately for their efficacy and safety.[3] The importance of employing both in vivo and in vitro models cannot be overstated, as these models help to elucidate the complex neurobiology underlying depression and guide the selection of appropriate therapeutic agents.[4] Experimental animal models are critical for understanding pathophysiology and developing new treatments for depression. An ideal animal model should have face, concept, and predictive validity. It is difficult to create a comparable model using mice that mimics all of the depressive signs that humans experience. Aside from the traditional stress-induced depression models, the researchers are creating and testing novel models involving neuro-inflammation, genetic and epigenetic dysregulation, and optogenetic techniques.[6] This review provides a comprehensive overview of current methodologies used for screening antidepressants, focusing on in vitro, in vivo, and ex vivo models, and highlighting Phytoconstituents for Antidepressant.

Phytoconstituents for Antidepressant

1. **Flavonoids:** Quercetin, a flavonoid present in fruits and vegetables, has received interest due to its potential antidepressant qualities. As a powerful antioxidant and anti-inflammatory, quercetin may work by altering important neurotransmitters involved in mood regulation, such as serotonin and dopamine. These neurotransmitters play an important role in maintaining mental balance, and changes in their levels are frequently associated with depressive illnesses. According to research, quercetin may help alleviate depression symptoms by modulating certain neurochemical pathways, making it a viable natural compound for the treatment of mood disorders. [6,7]
2. **Alkaloids:** Harmine, an alkaloid produced from the ayahuasca plant, has demonstrated promise antidepressant activity due to its ability to block monoamine oxidase (MAO) enzymes. MAO enzymes break down vital neurotransmitters like serotonin, dopamine, and norepinephrine, which are essential for mood regulation and emotional well-being. By blocking these enzymes, harmine may help maintain higher levels of these neurotransmitters, potentially leading to better mood and fewer depressed symptoms. This method shows that harmine may act as a natural antidepressant, particularly in cases of serotonin deficit.[8]
3. **Saponins:** Ginsenosides, the active chemicals present in ginseng, have been shown to have antidepressant properties by altering the hypothalamic-pituitary-adrenal (HPA) axis, which regulates the body's stress response. HPA axis dysregulation is frequently associated with persistent stress, anxiety, and depression. Ginsenosides influence this mechanism, allowing them to modulate cortisol levels and lower stress, potentially alleviating depression symptoms. Ginsenosides' potential to influence the HPA axis suggests that they may play a therapeutic function in the management of stress-related mood disorders, making ginseng a valuable natural medication for mental health support.[9]



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4. **Terpenoids:** Linalool, a terpenoid often found in lavender, is known for its relaxing and anxiolytic characteristics, making it a good candidate for antidepressant treatment. Linalool has been proven in studies to have a favorable effect on the central nervous system by lowering anxiety and stress, both of which are linked to depression. Its calming effects on the brain may improve mood and reduce depression symptoms by encouraging relaxation and lowering mental stress. Linalool's natural anxiolytic effects have drawn interest as a potential therapeutic alternative for treating depression and anxiety-related diseases. [10,11,12]
5. **Polyphenols:** Resveratrol, a polyphenolic molecule found in grapes and red wine, has received interest due to its potential antidepressant properties. According to research, resveratrol may increase the production of serotonin, a neurotransmitter important for mood regulation, resulting in better emotional well-being. It also has neuroprotective qualities, which protect neurons from injury and promote general brain health. These combined results show that resveratrol may play an important role in reducing depressed symptoms, making it a viable natural compound for mental health support and mood disorder management.[13,14]
6. **Essential oils:** Linalool, found in lavender oil, and bergamot oil are essential oils known for their depressive properties, notably in aromatherapy. These oils have been demonstrated to have soothing effects on the central nervous system, which can greatly alleviate feelings of anxiety and sadness. The soothing perfume of lavender and the energizing scent of bergamot combine to improve mood, induce relaxation, and reduce stress. Research suggests that inhalation or topical use of these essential oils can be helpful supplementary therapy for treating depression and anxiety.[15]
7. **Tannins:** Tannic acid, a kind of tannin found in abundance in tea leaves, has been studied for its possible antidepressant properties due to its capacity to control the body's stress response. Tannic acid, by altering stress-related hormones and neurochemical pathways, may help alleviate the physiological and psychological effects of stress, both of which are associated to depressive disorders. According to research, drinking tannin-rich liquids like tea may improve mood and contribute to mental health. These qualities make tannic acid a viable natural chemical for further investigation in the treatment of depression and stress-related disorders.[16,17]

In Vivo Models

Rodent Models

Rodents are the most commonly utilized species for antidepressant testing due to their short lifetime, genetic resemblance to humans, and simplicity of manipulation. Several rat behavioral assays have been validated as predictive models for antidepressant efficacy.

Forced Swim Test (FST):[18]

The forced swim test is a mouse behavioral test used to evaluate antidepressant medicines, the efficacy of novel substances, and experimental manipulations aiming at producing or preventing depressive-like states. Mice are placed in an impenetrable clear tank filled with water, and their escape-related movement behavior is recorded. The forced swim test is simple to perform consistently and requires little specialist equipment. The successful administration of the forced swim test necessitates strict adherence to certain procedural parameters and the minimizing of unnecessary stress on the mice.

Materials: The water tanks, Thermometer, Timer, Dividers, White noise generator, Drying paper and heat lamp.

Behavioral Procedures

To conduct the Forced Swim Test (FST), ensure counterbalancing of treatment groups and rotate mice across different tanks to avoid bias. Set up the camera close to the tanks for high-resolution video, and fill the tanks with tap water at 23-25°C, adjusting temperature if necessary. Use white noise if needed to mask external sounds. Acclimate mice in the testing room if necessary. Begin video recording, gently place mice in the tanks, and ensure the procedure minimizes disruptions. Test each mouse for six minutes, with special care taken to avoid startling them. Monitor behavior and intervene if a mouse appears distressed. After testing, remove the mice, dry them, and return them to their home cages. For analysis, measure the time each mouse is mobile during the last four minutes of the test.



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Subtract mobility time from 240 seconds to calculate immobility time. To prevent bias, cover the stopwatch display except for milliseconds. New observers should undergo training to ensure consistent behavioral scoring, with inter-observer reliability tests conducted before analyzing experimental data.

Behavioral Analysis

In the Forced Swim Test (FST), the last four minutes of the six-minute test are typically analyzed to avoid the initial burst of activity that could obscure treatment effects. Mobility is measured by recording active movements, while immobility is calculated as the time when the mouse shows no movement except to stay balanced in the water. Subtle movements like floating or momentum-driven drifting are excluded from mobility scoring. Video analysis is done via PC using stopwatch software, with controls for ensuring consistency and avoiding bias. Observers are trained extensively, scoring alongside experienced analysts to achieve high inter-observer reliability. Differences in mobility across mouse strains, sexes, or new genetic models require re-testing for consistency. The lab maintains an internal standard for comparison and training purposes.

Tail Suspension Test (TST):[19]

The tail-suspension test is a mouse behavioral test useful in the screening of potential antidepressant drugs, and assessing of other manipulations that are expected to affect depression related behaviors. Mice are suspended by their tails with tape, in such a position that it cannot escape or hold on to nearby surfaces. During this test, typically six minutes in duration, the resulting escape-oriented behaviors are quantified. The tail-suspension test is a valuable tool in drug discovery for high-throughput screening of prospective antidepressant compounds.

Materials

Suspension Box, Tape, Timer, White noise generator, cleaning supplies, Climb stoppers (optional: dependent upon strain used).

Behavioral Procedures

Ensure proper counterbalancing in the Tail Suspension Test (TST) by rotating mouse positions and representing all treatment groups equally in each session. Position the camera close for optimal resolution. Prepare and mark tape fragments before the session. If using a white noise generator, start it before introducing the mice to the testing room, keeping the noise level consistent for all animals. Acclimate the mice if needed. For strains prone to tail climbing, use Climb stoppers. Apply tape to the ends of the tails, leaving 2-3 mm uncovered, and prevent tangling by sticking the middle portion to the inner walls of the cage. Begin recording before suspending the mice in a counterbalanced order, ensuring the camera view is unobstructed. After the session (usually six minutes), return the mice to their homecage and carefully remove the tape. Clean the apparatus after each session.

Behavior Analysis

In the Tail Suspension Test (TST), the entire six-minute session is analyzed, as mice tend to show immobility earlier compared to the Forced Swim Test (FST). The analysis focuses on measuring mobility time, with overt escape behaviors like reaching for the walls and strong body movements counted as mobility. Subtle movements, such as front leg movements without hind leg involvement or pendulum-like swings, are excluded. In the lab, video recordings are uploaded for analysis, and mobility is tracked using on-screen stopwatch software. To minimize bias, the total elapsed mobility time is hidden, showing only the milliseconds to prevent the observer from forming pre-emptive judgments. Multiple mice on screen should be covered to avoid distractions during analysis. New observers undergo rigorous training to ensure inter observer reliability before analyzing actual experimental data. Observers first watch experienced analysts, then score together until they gain confidence. A high level of consistency is required between observers, with archived training data serving as a reference. Additionally, differences in mobility between strains, sexes, and new genetic models require re-assessment of reliability to account for behavioral variability.



**Vivek T. Kumbhar et al.,****Chronic Mild Stress (CMS) Model**

The chronic mild stress (CMS) model of depression is frequently used as a model. In this model, rats or mice are persistently exposed to a steady bombardment of unpredictable micro-stressors, resulting in a slew of behavioral alterations, including decreased reaction to rewards, which is a behavioral correlate of the clinical core symptom of depression, anhedonia. The canonical form of the paradigm measures reward sensitivity by frequent testing in which the animal is provided access to a highly desired sweet solution, or a choice between a sweet solution and plain water.[20]

Materials

Standard laboratory animals, stressors such as cage tilt, food and water restriction, changes in light/dark cycles, crowding, and noise are all necessary. Standard housing and enrichment tools are also utilized to keep animals under controlled settings, as well as specialized equipment for behavioral testing, such as sucrose preference tests or forced swim tests.

Procedure

The behavioral approach is subjecting mice to a series of random mild stresses over the course of many weeks. These stressors are introduced at random, preventing the animals from adjusting to or anticipating the stress. Food and water restriction, changed lighting conditions, social isolation, and exposure to unfamiliar or stressful surroundings are all common stressors. The idea is to replicate the persistent and unpredictable type of stress found in human depression.

Behavioral Analysis

During the behavioral study, numerous tests are used to examine the animals' responses to persistent stress. The sucrose preference test is used to assess anhedonia, in which decreased sugar consumption implies a loss of pleasure, a core sign of depression. Other tests, such as the forced swim test and the tail suspension test, assess immobility time, which suggests despair-like behavior. The results of these behavioral assessments are compared between stressed and control groups to determine the effects of persistent mild stress.[21]

Non-Rodent Models

While rats predominate in antidepressant screening, non-rodent models like zebrafish (*Danio rerio*) are gaining popularity due to their genetic closeness to humans, transparency throughout early development, and simplicity of genetic modification. Although zebrafish models provide advantages in drug screening by allowing for high-throughput in vivo testing, their translational utility in simulating complex human emotional states is debatable.

Zebrafish model[22]

Zebrafish (*Danio rerio*) are increasingly being used as a novel and successful model organism for research into major depressive disorders (MDD). Given their genetic and physiological similarities to humans, as well as the benefits of transparent embryos, quick development, and ease of pharmacological treatment, zebrafish have emerged as an important tool for investigating the underlying causes of depression. The authors examine the many behavioral assays and stress paradigms utilized in zebrafish investigations, emphasizing their importance in studying depressive-like behaviors and determining the efficacy of antidepressant treatments. This study highlights the utility of zebrafish as a model system for bridging the gap between molecular biology and behavioral neuroscience in the context of MDD.

Materials

Zebrafish (*Danio rerio*) are utilized as model organisms because of their genetic closeness with humans, transparent embryos, and quick development. The study makes use of specifically designed tanks for behavioral experiments, as



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well as video capturing technology to analyze fish behavior. Zebrafish responses can also be evaluated using pharmacological treatments such as antidepressants and stress-inducing chemicals.

Procedure

To simulate conditions associated with depression, the researchers subjected zebrafish to a variety of stress paradigms, including social isolation, exposure to novel surroundings, and light/dark tests. Behavioral techniques such as the innovative tank diving test, which places zebrafish in a new setting and analyzes their vertical swimming patterns, were employed to assess stress and anxiety-like behavior. To assess the impact of chronic stressor exposure on behavior and physiology, antidepressant medications were administered concurrently.

Evaluation

The major evaluation criteria included alterations in zebrafish behavior, notably increased immobility, changed swimming patterns, and decreased exploration, all of which indicate depressive-like states. Antidepressant effects were tested by reversing these actions. Furthermore, molecular assays such as gene expression profiling were used to monitor changes in stress-related pathways.

In Vitro Models

In vitro models offer the advantage of being cost-effective, high-throughput, and less ethically contentious than *in vivo* studies. These models involve cellular assays, receptor-binding studies, and genetic manipulation to explore antidepressant activity at the molecular and cellular level.

Cell-Based Assays[22,23]**Materials**

Cell-based assays often use neuronal or neuroblastoma cell lines (e.g., SH-SY5Y or PC12), freshly cultured neurons, or iPSC neurons. Culture conditions, growth nutrients, and supplements such as fetal bovine serum (FBS) or neurotrophic factors are required to sustain cell viability. Test chemicals (possible antidepressants) and reagents for evaluating cellular responses, such as MTT (viability) or antibodies for signaling pathways such as CREB or BDNF, are also utilized.

Procedure

Cells are grown in multi-well plates under ideal circumstances. After achieving the desired confluency, the test chemicals are added at varied quantities. The cellular response is assessed after a treatment time (which can last anywhere from hours to days depending on the test). Cell viability tests, such as MTT or lactate dehydrogenase (LDH) release assays, as well as signaling pathway activation assays (e.g., CREB or BDNF levels) using Western blotting or ELISA, are common.

Evaluation

Potential antidepressants' effects are assessed using changes in cell survival, neurite outgrowth, and the activation of neuroprotective and neuroplasticity pathways. Positive outcomes are often characterized by enhanced cell survival, neurite length, or overexpression of proteins linked with antidepressant effects (for example, BDNF, CREB). The data is statistically examined to establish the efficacy and therapeutic potential of the test substances.

Receptor Binding Assays[24,25]**Materials**

Receptor binding experiments often use brain tissue or cell membranes that express specific receptors (for example, serotonin 5-HT, dopamine D2, or adrenergic receptors). Radiolabeled ligands, such as [³H]-serotonin or [³H]-ketanserin, are often employed to measure receptor-ligand interactions. Buffer solutions, test chemicals (possible antidepressants), and a scintillation counter for measuring radioactivity are all essential components.



**Vivek T. Kumbhar et al.,****Procedure**

Membrane preparations containing target receptors are treated with radio labeled ligands and increasing quantities of test chemicals. The test chemicals compete against the radio ligand for receptor binding. Following incubation, the free ligand is removed from the bound fraction via filtration or centrifugation. The bound radio ligand is subsequently quantified with a scintillation counter, which provides information about the test compound's binding affinity.

Evaluation

The assay analyzes the test compound's capacity to displace the radio labeled ligand from the receptor. Data is evaluated to determine the compound's binding affinity (which is commonly represented as IC₅₀ or K_i values). A lower IC₅₀ implies better binding affinity, implying a stronger contact with the receptor. The efficacy of the test substance in modifying receptor function can help determine its potential as an antidepressant.

High-Throughput Screening (HTS)**Materials**

HTS necessitates sophisticated automated systems capable of processing vast amounts of data. Microtiter plates (typically in 384- or [1]536-well formats), test compounds from huge chemical libraries, biological response detection reagents (e.g., fluorescent or luminous markers), and liquid handling robotic systems are all important ingredients. Plate readers and other assay detection systems are used to monitor cellular or molecular responses.

Procedure

HTS begins with the preparation of microtiter plates, often in 384- or 1536-well configurations, containing cells or biochemical targets related to antidepressant effect, such as neurotransmitter transporters, receptors, or enzymes like monoamine oxidase. Automated robotic equipment then distributes small amounts of test chemicals from enormous chemical libraries into each well. These substances are evaluated for their capacity to influence the target's activity. Following incubation, detection reagents such as fluorescent, luminescent, or colorimetric markers are added to determine the assay's biological response. The entire procedure is intended for high-speed, high-volume data collection, allowing thousands of chemicals to be evaluated concurrently. Following the test, the plates are examined using detection tools such as automatic plate readers, which record signals proportional to the activity of each component. The obtained data is processed and statistically analyzed to find active chemicals (hits) that exhibit considerable activity when compared to controls. These hits are chosen based on parameters such as the Z'-factor, which assesses assay quality, and then prioritized for secondary validation. Promising compounds with antidepressant efficacy are tested further in more specialized and complicated assays, such as secondary screens and *in vivo* models, to confirm their therapeutic potential.

Evaluation

HTS generates large datasets where the effects of each compound are analyzed for their ability to induce or inhibit specific biological responses. Hits are identified based on statistical thresholds (e.g., Z'-factor) that indicate significant activity. These hits are further evaluated for their potential as antidepressants by comparing their activity to known reference compounds. Hits with favorable activity profiles are advanced to secondary validation assays.

Computational Approaches

Computational approaches to antidepressant development use computer-based tools and algorithms to forecast new drug candidates' efficacy, safety, and mechanisms of action. Molecular docking, virtual screening, and quantitative structure-activity relationship (QSAR) modeling are all used to mimic how chemicals interact with biological targets such neurotransmitter receptors and enzymes. These methods, which use databases of known compounds and targets, enable researchers to quickly screen huge chemical libraries, select interesting candidates, and estimate pharmacokinetics and toxicity profiles. Computational techniques considerably speed up the drug discovery process,



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lowering the requirement for early-stage experimental testing and directing compound selection for future development. [26,27]

In Silico Screening: [28,29]**Material**

In silico screening makes use of computational software and databases. Chemical libraries (molecular structure databases like as PubChem or ZINC), target protein structures (for example, from the Protein Data Bank), and molecular modeling tools such as molecular docking software (AutoDock, Schrödinger, etc.) and virtual screening platforms are also important resources. Advanced algorithms and machine learning models are also used to forecast drug-target interactions and pharmacokinetics.

Procedure

In silico screening begins by identifying molecular targets involved in depression, such as serotonin transporters or monoamine oxidase. The 3D structures of these targets are determined, and test compounds from virtual chemical libraries are tested against them using molecular docking techniques. The docking software models how well each molecule fits into the target's active site, assigning binding affinity ratings based on molecular interactions (e.g., hydrogen bonding, hydrophobic interactions). Virtual screening algorithms can quickly sift through thousands of chemicals and predict their effectiveness in binding to the target. Once prospective drugs with positive docking scores have been found, additional computer analyses are performed to evaluate their pharmacokinetic features (absorption, distribution, metabolism, excretion, and toxicity, or ADMET). Machine learning models can also anticipate adverse effects, efficacy, and off-target interactions. Selected compounds with significant target interactions and favorable ADMET profiles are identified as candidates for further *in vitro* and *in vivo* validation, expediting the drug development process and lowering the time and cost of experimental screening.

Machine Learning and Artificial Intelligence (AI) [30,31,32]**Material**

Machine learning (ML) and artificial intelligence (AI) models require large datasets that include information about chemical structures, drug-target interactions, pharmacokinetics, and clinical outcomes. Curated databases such as ChEMBL, DrugBank, or PubChem contain information on bioactive chemicals, their characteristics, and mechanisms. ML frameworks such as Python-based libraries (e.g., TensorFlow, Scikit-learn) and AI tools (e.g., deep learning neural networks) are used to train models for therapeutic efficacy and side effects.

Procedure

Data preparation is the initial step in drug discovery using machine learning and artificial intelligence. Chemical, biological, and pharmacological data are collected and cleaned to assure accuracy. Using this information, algorithms are trained to spot patterns linked with antidepressant efficacy or toxicity. Supervised learning techniques use labeled datasets to educate algorithms to anticipate outcomes such as receptor binding affinity, whereas unsupervised learning can help find novel drug-target interactions that lack established labels. Deep learning methods, such as convolutional neural networks (CNNs), are used to assess complicated chemical characteristics and predict bioactivity using structural properties. AI also aids in product selection by predicting pharmacokinetics, toxicity, and off-target effects. Once trained, the algorithm can evaluate novel chemical compounds and score their antidepressant potential using previously acquired patterns. Furthermore, AI systems can examine genetic data to find biomarkers connected to depression, allowing for more tailored therapy recommendations. The process speeds up drug discovery by focusing on the most promising candidates for experimental validation, optimizing resources, and shortening time to market.



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Challenges and Future Directions

Despite major advances in antidepressant screening methods, some problems remain. One key concern is the complexity and variety of depression, which can lead to variations in drug reactions between individuals. Current models may not adequately represent the disorder's complex character, reducing their predictive value. Furthermore, many standard in vitro and in vivo experiments do not effectively imitate the human brain's environment, which might lead to incorrect results.³³ Future research should focus on establishing more comprehensive models that account for genetic, epigenetic, and environmental factors that influence depression. Organ-on-a-chip technologies and patient-derived iPSC models can improve the utility of screening tests. Furthermore, combining AI and machine learning with developing omics technologies (genomics, proteomics, and metabolomics) will allow for a more personalized approach to antidepressant development, aiding in the identification of biomarkers for treatment response and optimizing medication selection. Finally, addressing present obstacles and developing antidepressant medicines will require a multidisciplinary strategy that incorporates computational approaches and experimental validation. [34,41,42]

Advances in Humanized Models

Humanized models provide a big step forward in the research of depression and the development of effective medicines. These models strive to closely imitate human physiology and pathology, resulting in more relevant data than standard animal models. Recent advances in humanized models include the use of human induced pluripotent stem cells (iPSCs), which may differentiate into a variety of cell types, including neurons, allowing researchers to examine depression causes at the cellular level. These models enable the investigation of genetic variants and their effects on medication response, opening the door for personalized treatment.²³ Another interesting option is the creation of organ-on-a-chip technologies that mimic the human brain's microenvironment. These systems can reproduce the blood-brain barrier and neural networks, allowing researchers to study drug delivery, pharmacokinetics, and toxicological effects in a controlled environment.[24] Furthermore, advances in 3D bioprinting allow for the production of complex tissue structures that better mimic the architecture of human brain tissue. These models improve our understanding of neurodevelopment, synaptic connection, and the impact of antidepressants on neuroplasticity. Overall, incorporating these humanized models into antidepressant research opens up new paths for drug discovery, increasing the likelihood of developing successful depression treatments. [35,36]

Biomarkers and Omics Technologies

Biomarkers and omics technologies are critical to enhancing our understanding of depression and discovering new antidepressants. Biomarkers, which are observable indications of biological processes, disease states, or pharmacological reactions, can assist identify people who are at risk of depression, predict treatment outcomes, and track therapeutic efficacy. The integration of genomes, proteomics, metabolomics, and transcriptomics enables researchers to identify molecular markers related with depression and antidepressant response, allowing for more tailored therapy approaches. Omics technologies allow for extensive profiling of biological materials, showing complex relationships between genes, proteins, and metabolites involved in depression. For example, genomics can discover genetic polymorphisms associated with depression, but proteomics can reveal changes in protein expression levels in response to treatment. Metabolomics provides insights into metabolic pathways that are changed in depressive illnesses, which might help identify therapeutic targets. Together, these technologies improve the ability to identify novel biomarkers, streamline drug development procedures, and develop targeted therapy tactics, ultimately leading to more effective depression treatments. [37,38,39,40]

CONCLUSION

In conclusion, different phytoconstituents obtained from natural sources show promise antidepressant properties, providing a supplementary strategy to addressing depression and anxiety. Flavonoids (quercetin), alkaloids



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(harmine), saponins (ginsenosides), terpenoids (linalool), polyphenols (resveratrol), essential oils (lavender and bergamot), and tannins (tannic acid) have all been shown to modulate key neurochemical pathways, reduce stress, and promote overall mental health. While these plant-based elements have significant therapeutic promise due to processes such as serotonin augmentation, HPA axis control, and neuroprotection, more research is needed in clinical settings to fully understand their efficacy, safety, and mechanisms of action. Nonetheless, these phytoconstituents represent a viable option for developing natural alternatives or adjuncts to traditional antidepressant therapy.

Antidepressant screening models have advanced dramatically, employing a diverse set of techniques to speed drug development and improve therapeutic effects. Traditional *in vitro* and *in vivo* techniques, such as cell-based and receptor-binding tests, forced swim test, tail suspension test, offer important insights into the molecular and cellular effects of prospective antidepressants. High-throughput screening (HTS) technologies have made it easier to identify interesting compounds, while *in silico* methodologies and computational tools provide a cost-effective and quick way to forecast medication efficacy and safety. Machine learning (ML) and artificial intelligence (AI) have changed the sector by allowing the analysis of huge datasets, optimizing chemical selection, and improving customized medicine approaches. As antidepressant research progresses, the integration of these various techniques promises to result in more effective and focused medicines that address the intricacies of depression at multiple physiological levels. By merging classic experimental procedures with cutting-edge computational technologies, researchers are better able to address drug discovery hurdles, thereby enhancing patient outcomes and quality of life.

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Assessment of Quality of Life in Cegana Vaatham (Cervical Spondylosis) Patients undergoing Varmam Therapy

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ABSTRACT

Varmam treatment is part of *Siddha* medicine, an ancient healing practice that stimulates key energy centres called "*varmam* points." This therapy attempts to improve prana flow and restore equilibrium, particularly in musculoskeletal diseases. Combining *varmam* therapy with herbal therapies provides a comprehensive approach to wellness. The study was designed to observe the quality of life (QOL) of patients with *Ceganavaatham* which may be correlated with Cervical spondylosis (CS) under *varmam* treatment. 20 subjects were followed for 30days and their quality of life is assessed with Neck Disability index questionnaire and Short Form-36 health survey questionnaire. SPSS was used to perform statistical analysis with Wilcoxon Signed rank test. A probability value of <0.05 was considered as statistical significance. The Statistical analysis of SF-36 scores and NDI scores before and after *varmam* treatment with Wilcoxon signed-rank test also showed statistical significance results (P<0.001). The results of this study demonstrated that *Varmam* treatment gives significant improvement in the quality of life in subjects with *Ceganavaatham* (Cervical spondylosis)

Keywords: VARMAM, SIDDHA, CEGANA VAATHAM, CERVICAL SPONDYLOSIS, QUALITY OF LIFE





INTRODUCTION

Based on the literature evidences, the Siddha system of medicine focuses on maintaining a balance of 3 humors and 7 constituents of the body. Diseases are believed to arise when there is an imbalance in these humors and constituents. They are classified into various types, such as *Vaathadiseases*, *Pithadiseases*, and *Kaba diseases*, based on the specific imbalance observed.[1] *CeganaVaatham* is categorized as a *Vaatha* disease and shares symptoms similar to cervical spondylosis, including pain below the neck to the inguinal level, radiating pain in the hands, body heaviness, giddiness, burning sensation in the eyes, numbness, and tingling sensations throughout the body.[2] In *Siddha* medicine, treatment includes various internal medicine, external medicine each of 32 types, and it also possess a unique therapy known as *Varmam* therapy. *Varmam* therapy focuses on manipulating specific points known as *Varmam* points, which are believed to be crucial for the flow of vital energy in the body.[3] This therapy is particularly employed for musculoskeletal disorders, addressing issues with bones, nerves, and muscles.[4] Neck discomfort is a significant issue in modern life, though not the most common musculoskeletal disorder. The age-standardized prevalence of neck pain is 3551.1 per 100,000 population, with an incidence of 806.6 per 100,000.[5] Cervical spondylosis (CS) is an age-related degenerative condition affecting the cervical spine, typically at levels C5-C6 and C6-C7. It causes pain, tingling, numbness, and weakness in the upper extremities, leading to disability. Factors contributing to CS include aging, occupational stress, neck injuries, and genetic predisposition.[6] *Varmam* therapy is widely used in the management of *Vaatha* type of pain related conditions among the *Siddha* system of medicine. The quality of life in *CeganaVaatham* patients is affected by the pain interrupting their normal day to day activities like reading, sleeping, personal care, work etc. By reducing the pain their quality of life may improve. Thus, an attempt was made to study the Quality of Life (QOL) in *CeganaVaatham* patients using Short Form-36 health survey questionnaire (SF-36) and Neck disability index (NDI).

MATERIAL AND METHODS

Sample and subjects

An observational study was conducted to analyze the impact of *Varmam* treatment on the quality of life of patients diagnosed with Cervical Spondylosis (*CeganaVaatham*). The study, conducted between February and June 2023 at *Varmamaruthuvam* OPD, AyothidossPandithar Hospital, National Institute of Siddha in Chennai, aimed to evaluate changes using the Short Form-36 Health Survey Questionnaire and Neck Disability Index (NDI) over a 30-day period. The inclusion criteria comprised individuals of all genders aged between 30 to 60 years, diagnosed with Cervical Spondylosis exhibiting symptoms such as neck pain radiating to the arms, numbness, and neck stiffness. Patients had to provide informed consent and be undergoing *Varmam* treatment. Exclusion criteria included patients with a history of cervical spine fracture, Pott's disease, spinal stenosis, or Ankylosing spondylitis. Out of 54 screened patients, 20 met the inclusion and exclusion criteria and consented to participate. The study received ethical clearance from the Institutional Ethical Committee of the National Institute of Siddha (NIS/23/IEC/2022/MP/11) and was registered in the Clinical Trials Registry of India (CTRI/2023/02/049697). All participants provided informed consent. This research aims to contribute to understanding how *Varmam* treatment may improve the quality of life and reduce disability in Cervical Spondylosis patients.

Clinical evaluation

The clinical evaluation process for patients with *CeganaVaatham* involves gathering detailed sociodemographic and clinical data, along with utilizing specific assessment tools to gauge their quality of life.

Data Collection

Comprehensive information is gathered, including age, gender, height, weight, BMI, education, occupation, income, socio-economic status, marital status, personal habits, and dietary patterns. A detailed clinical history is also obtained, covering comorbidities, traumatic events, and other medical backgrounds.





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Assessment Tools

Neck Disability Index (NDI): NDI aims to assess the impact of neck pain on day-to-day activities through 10 items. Each domain is rated from 0 to 5, reflecting varying degrees of severity. The total score, which ranges up to 50, indicates the level of disability, with higher scores indicating greater impairment.[7] Short-Form 36 Health Survey (SF-36): This survey measures various dimensions of health-related quality of life. It consists of 36 items in 8 groups, covering aspects like vitality, physical functioning, physical and emotional well-being, social functioning, general health perception, bodily pain and mental health. Scores for each scale range from 0 to 100 where higher scores indicate the better health and lower scores indicate more limitations.[8] This structured approach allows healthcare providers to comprehensively assess the impact of *Ceganavaatham* on patients' lives, integrating objective measurements with patient-reported outcomes to guide effective treatment and management strategies.

Data analysis

Data collected from patients with *Ceganavaatham* were meticulously organized in Microsoft Excel, with variables allocated to columns and patient records to rows. Statistical analysis was conducted using SPSS, which included the Wilcoxon Signed Rank test to evaluate changes over time or between related groups. Descriptive statistics such as frequency distributions and cross-tabulations summarized categorical variables, while visual aids like bar diagrams and pie charts depicted variable distributions. Mean and Standard Deviation summarized quantitative data, and percentages summarized qualitative variables. A significance level of <0.05 was considered as statistical significance. This systematic approach ensures comprehensive analysis and clear presentation of data, facilitating informed decision-making in treatment strategies for *Ceganavaatham* patients.

Standard operating procedure for Varmam therapy for Ceganavaaatham patients

Varmam therapy was done under the supervision of the Guide and monitored by the Head of the Department. The therapy was given for about 4 sittings (weekly once in 1 month) after monitoring the vitals and eligibility of the patient.

RESULTS

Based on the sociodemographic data of patients with *Ceganavaatham*, subjects were predominantly male (65%), married (65%) and in the age range of 41-50 (50%) with normal BMI (60%). Most of the patients were skilled and semi-skilled workers with high school qualifications. In case of socio-economic status majority comes under Upper lower IV (60%). The NDI scores before treatment were recorded as among 20 patients, 2 patients scored between (24-34 points) with severe disability in daily activities and other 18 scored (34 – 50 points) with complete disability in daily activities due to pain. After 30 days in treatment in Varma Maruthuvam OPD, among 20 patients 2 patients scored (15 – 24 points) with mild disability, 17 patients scored (24- 34 points) with moderate disability in activities and 1 patient scored (35 – 50 points) with severe disability in performing their day-to-day activities because of pain. (Table- 2 & 3) The SF-36 Health survey questionnaire assess the patients with 8 domains and their observations were found to be as follows. In vitality domain, the average value before treatment was found to be 39% and was increased to 52.25% after the treatment with the maximum score of 65% having good amount of energy in performing their activities. In physical functioning, the average value before treatment was found to be 33.75% and was increased to 72.5% after the treatment with maximum score of 85% like better changes in walking, carrying things, stepping stairs. In bodily pain, the average value before treatment was found to be 19.75% and was increased to 47.6% after the treatment with maximum score of 67% as reduction in pain and its interruption in activities. In General health, the average value before treatment was found to be 13.5% and was increased to 51.35% after the treatment with maximum score of 70% as improvement in overall health perspective. In physical role functioning and emotional role functioning, the average value after treatment was found to be 50% and 51.62% as accomplishment of their usual work and relieving from depression and anxiety. In Social role functioning, the average value before treatment was found to be 21.25% and was increased to 52.5% after the treatment with maximum score of 62.5% like visiting family, friends, neighbors or groups. In mental health, the average value before treatment was found to be 36.2% and was increased to 67.8% after the treatment with the maximum score of 80% as





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feeling calm and peaceful, not being downhearted and nervous person.(Table- 4 & 5)

DISCUSSION

This article examines the socio-demographic data, clinical presentations and quality of life (QoL) aspects of patients diagnosed with *CeganaVaatham* (Cervical spondylosis) over a six-month study period. The current studies showed that the prevalence of neck pain is equally distributed in genders and women are mostly affected.[9] In this study those who predominantly participated were male (65%) and married (65%). Most cases come under the age category between 41-50 years (50%) in relation with age standard prevalence of neck pain in recent studies.[10] Most of the patients were skilled and semi-skilled workers (65%) with high school qualifications. There is a high prevalence of neck pain in persons who has long working hours (>8 hours). In case of socio- economic status majority comes under Upper lower IV (60%). A meta-analysis on Socioeconomic status and occurrence of chronic pain revealed that there is an association between lower SES and incidence of chronic pain.[11] Various case reports and prospective observational case series on *Varmam* therapy shows promising results in pain management. [12,13] This observational study focused on how the pain reduction by *Varmam* therapy in Cervical spondylosis patients had impact in improving their quality of life. Data from NDI scale showed most patient scored 4 and 5 in each domains representing severe and worst pain at the moment, difficulty in handling weights, undertaking personal care, reading, developed headache with sleep disturbances. The patients also faced difficulty in driving, unable to concentrate on work and recreation. After *varmam* treatment the most patients showed good improvement in Sleeping, personal care, reduction in pain intensity and headache. Moderate improvement in reading, concentration, work and recreation. Mild improvement in lifting weights and driving. Data from SF36 showed good improvement comparing before and after *varmam* treatment as good amount of energy in performing their activities like walking, carrying things, stepping stairs due to reduction in pain.

Mental health of the patients showed good results in Social and emotional role as relieving from depression, visiting family and friends. The analysis of SF-36 and NDI scores before and after treatment revealed significant findings using the Wilcoxon signed-rank test. When discussing *Varmam* therapy for cervical spondylosis, it's important to delve into its underlying principles and how they may relate to the condition. One potential benefit of *Varmam* therapy for cervical spondylosis lies in its holistic approach to healing. Rather than simply treating the symptoms, *Varmam* therapy aims to maintain the vital energy balance. Proponents suggest that by stimulating specific *varmam* associated with the cervical region, circulation can be improved, energy blockages can be cleared, and the body's innate healing mechanisms can be activated. Moreover, *Varmam* therapy often incorporates various techniques such as massage, pressure, and manipulation, which can help alleviate muscle tension and promote relaxation. For individuals with cervical spondylosis, these techniques may provide relief from the discomfort associated with muscle spasms and stiffness in the neck and shoulders. However, it's essential to approach *Varmam* therapy for cervical spondylosis with caution and under the guidance of a qualified practitioner. While many people report positive experiences with alternative therapies like *Varmam*, scientific evidence supporting its effectiveness specifically for cervical spondylosis is limited. Therefore, it's crucial to integrate *Varmam* therapy into a comprehensive treatment plan that may include conventional medical interventions such as physical therapy, medication, and lifestyle modifications.

CONCLUSION

In conclusion, while *Varmam* therapy offers a unique approach to addressing cervical spondylosis, further research is required to get a comprehensive understanding of its efficacy and mechanisms of action. Nevertheless, for individuals seeking alternative or complementary therapies, exploring *Varmam* therapy under the guidance of a knowledgeable practitioner may offer potential benefits in managing symptoms and improving overall well-being.



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AUTHOR CONTRIBUTIONS

Sasikumar E developed the research idea, gathered the data, analyzed the results, and wrote the initial draft of the study. G Nivetha played a key role in interpreting the data and offering feedback on the study. P Samundeswari contributed to the data interpretation, carefully reviewed the study, and approved the final version. N J Muthukumar also reviewed the study, provided valuable input, and gave their final approval.

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Table 1: List of Varma points and their location used for the treatment

Step	Varmam	Location	Maathiraialavu	Manipulation	Frequency & Duration
1	Sara MudichuThadaval	At the level of spinous process of C7 vertebra	$\frac{1}{4}$ Maathirai	Use middle 3 fingers press & rotate clockwise 3 times and anti-clockwise 3 times	3 times & 30 seconds





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2	<i>Kakattai Kaalam</i>	2 fingers lateral to the junction of neck with shoulder near supraclavicular fossa	$\frac{1}{4}$ <i>Maathirai</i>	Press & release with middle 3 fingers	3 times & 15 seconds
3	<i>Savvu Varmam</i>	4 fingers below Yenthi kalam along the medial border of arm	$\frac{1}{4}$ <i>Maathirai</i>	Press & release with Thumb finger	3 times & 15 seconds
4	<i>Mani Banda Varmam</i>	Middle of the Wrist (Volar)	$\frac{1}{4}$ <i>Maathirai</i>	Press & release with Thumb finger	3 times & 15 seconds
5	<i>Ullangai Vellai Varmam</i>	Base of palm-junction of thenar & hypothenar muscles	$\frac{1}{4}$ <i>Maathirai</i>	Press & release with Thumb finger	3 times & 15 seconds
6	<i>Kai Kavali Varmam</i>	Web area between the thumb & index finger	$\frac{1}{4}$ <i>Maathirai</i>	Press with tip of the thumb & move upward medially	3 times & 15 seconds
7	<i>Yaenthivarmam</i>	Anterior aspect of the armpit	$\frac{1}{4}$ <i>Maathirai</i>	Press & release with middle 3 fingers	3 times & 15 seconds
8	<i>Piratharai Varmam</i>	Posterior aspect of the armpit	$\frac{1}{4}$ <i>Maathirai</i>	Press & release with middle 3 fingers	3 times & 15 seconds

Table 2: Descriptive statistics of NDI scores before and after Varmam treatment

NDI	N	Mean	SD	Minimum	Maximum
Before	20	39.1000	3.17722	32.00	43.00
After	20	19.1000	3.80996	13.00	29.00

Table 3: Wilcoxon signed-rank test for NDI scores before and after Varmam treatment

NDI	Ranks	N	Mean Rank	Sum of Ranks	P- Value	Inference
After-Before	Negative ranks	20 ^a	10.50	210.00	<.001	Significant
	Positive ranks	0 ^b	0.00	0.00		
	Ties	0 ^c				
	Total	20				

Table 4: Descriptive statistics of SF36 scores before and after Varmam treatment

Domain		N	Mean	SD	Min	Max
Vitality	Before	20	39.00	9.26	20.00	50.00
	After	20	52.25	4.99	45.00	65.00
Physical functioning	Before	20	33.75	10.49	20.00	60.00
	After	20	72.50	8.02	55.00	85.00
Bodily pain	Before	20	19.75	7.20	10.00	32.50



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	After	20	47.60	7.11	32.50	67.00
General health	Before	20	13.50	8.12	5.00	45.00
	After	20	51.25	9.85	35.00	70.0
Social role functioning	Before	20	21.25	10.01	12.50	50.00
	After	20	52.50	8.69	37.50	75.00
Mental health	Before	20	36.20	13.64	12.00	60.00
	After	20	67.80	7.39	52.00	80.00
Physical role functioning	Before	20	0.00	0.00	0.00	0.00
	After	20	50.00	18.13	25.00	75.00
Emotional role functioning	Before	20	0.00	0.00	0.00	0.00
	After	20	51.61	17.11	33.00	66.70

Table 5: Wilcoxon signed-rank test for SF36 scores before and after Varmam treatment

SF-36 SURVEY	Ranks	N	Mean Rank	Sum of Ranks	P- Value	Inference
Vitality	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	18 ^b	9.50	171.00		
	Ties	2 ^c				
	Total	20				
Physical functioning	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	20 ^b	10.50	210.00		
	Ties	0 ^c				
	Total	20				
Bodily pain	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	20 ^b	10.50	210.00		
	Ties	0 ^c				
	Total	20				
General health	Negative ranks	1 ^a	1.00	1.00	<.001	Significant
	Positive ranks	19 ^b	11.00	209.00		
	Ties	0 ^c				
	Total	20				
Social role functioning	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	19 ^b	10.00	190.00		
	Ties	1 ^c				
	Total	20				
Mental health	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	20 ^b	10.50	210.00		
	Ties	0 ^c				
	Total	20				
Physical role functioning	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	20 ^b	10.50	210.00		
	Ties	0 ^c				
	Total	20				
Emotional role functioning	Negative ranks	0 ^a	0.00	0.00	<.001	Significant
	Positive ranks	20 ^b	10.50	210.00		
	Ties	0 ^c				
	Total	20				





The Health Benefits of Ascorbic Acid in Management of Several Diseases : A Narrative Review

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ABSTRACT

Ascorbic acid also known as Vitamin C, is one of the most important and protective micronutrients. It is naturally present in some foods, added to others, and available as a dietary supplement. Humans, unlike most animals, are unable to synthesize vitamin C endogenously, so it is an essential dietary component. It mainly involves collagen, carnitine, and neurotransmitter bio synthesis. It also helps to maintain the shape and structure of the skin, bones, and connective tissue, It is the most potent water-soluble vitamin. vitamin C is also known as a good antioxidant which is responsible for protecting against viral infection and allergic reaction. Vitamin C protects cells from damage caused by free radicals, which are molecules produced when the body breaks down food or is exposed to pollution, tobacco smoke, and radiation. Vitamin C is effective in several human health benefits such as colds, scurvy, asthma, obesity, cardiovascular disease, diabetes, sepsis, atherosclerosis, etc. Research shows that people who took ≥ 700 mg/day of supplemental vitamin C had a 25% lower risk of coronary heart disease incidence than those who took no supplemental vitamin C. The exact role of vitamin c in the perspective of human health and disease is yet a mystery.

Keywords: Vitamin c;Anemia;Obesity;Cancer;Covid-19



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INTRODUCTION

Vitamin c essential nutrient which is important for our body so we need to add vitamin c which found in our diet because vitamin c is important for our body from toxic substances which is also known as oxidant. it is essential enzymes that make collagen, hormones, carnitine, genes (Bozonet and Carr, 2019). Vitamin c refers to collection of water soluble substance for example L-ascorbic acid, ascorbic acid, ascorbate. vitamin c help in making chemical and these chemical for help in our blood vessel make functioning and tissue building and growth and maintenance (Gordon et al., 2020). In past, we recommended the intake of micronutrient based on prevention of disease secondary to deficiency. In globally may people do not have enough micronutrient in body. many expert suggest that taking high intake of vitamin c good for our growth and maintenance of overall body health (Comunian et al., 2022). A crucial phyto nutrient in vitamin c one of the most important water soluble antioxidant which are present in some vegetable and fruits. vitamin c food contain a good amount of antioxidant which is help to fight against the free radical and suppresses the oxidation of LDL as a person suffering from atherosclerosis. previous researches show that vitamin c reduce the risk of chronic illness such as heart disease, cancer infection disease etc (Kongkachuicha et al., 2019). If you take a good amount of vitamin c it will help to enhance the level of antioxidant as well as fight against inflammation. Some clinical studies suggested that intake of vitamin c is stop because during pregnancy it became fatal growth, premature delivery and neonate death. vitamin c help to reduce the risk of rupture of the membrane and suggested 100mg for reduce the risk of urinary infection during pregnancy (Brown & Wright, 2020). Vitamin c covered across the placenta and maternal plasma level are decrease and daily intake of vitamin c need for lactation mother is around 60-85mg per day (Mousa et al., 2019). Increase the intake of vitamin c rich food such as citrus fruits and vegetable, raw broccoli, pepper, kiwi etc suggested that 400mg per day require for increase the plasma level of vitamin c at least 200 mg (Brown & Wright, 2020). Vitamin c is a water soluble vitamin c which is easily absorbed by our body but our body is unable to synthesized by own itself. the term vitamin c essential micronutrient protect our body from scurvy disease and it is introduced by Albert Szentgyorgyi in 1930s and help to prevent from damage to cell and many other benefit for our body are uses for energy and build up new things (Comunian et al., 2022). The purpose of this review paper to discuss about how vitamin c effect on different disease such as cardiovascular disease, obesity, anemia, covid-19 etc and their different dosage against particular disease.

HEALTH BENEFITS OF ASCORBIC ACID

Vitamin c and scurvy

Scurvy disease is very fatal disease and this disease describe in previous time. In 16th and 18th century James Lind who was famous physician he suggest that drink lemon juice for prevention from scurvy (Kazmierczak-Barańska et al., 2020). Human need 100 to 200mg of vitamin c from a daily diet and it reduce the risk of vitamin c deficiency and we need to treat if the scurvy is untreated because it is very harmful disease. We must take 10mg per day to avoid from scurvy (Mousavi, et al., 2019). Vitamin c prevent from scurvy and mostly research show different doses of vitamin c in scurvy. We need 40-220mg of vitamin c everyday this range given the diversity of guidelines (Carr & Lykkesfeldt, 2021). Lack of vitamin c in diet as a result illness because pneumonia and scurvy are linked with each other. Many people believe that vitamin c may affect a person refers to respiratory infection. In pre-diabetes and metabolic syndrome patient. Vitamin deficiency line with respiratory infection for example pneumonia. This disease is very fatal and cause many number of death in scurvy cases. Healthy manner intake of vitamin c is 200mg/day is enough and fight against the infectious disease (Rowe & Carr, 2020). International guidelines for daily intake of vitamin c are insufficient. it has already shown that 10mg of vitamin c in a daily basis is sufficient (Khalife et al., 2019). The treatment against scurvy is vitamin c supplementation. there are different dosages and treatment has been successful. treatment of abnormal eating pattern and it require long term nutritional counseling and therapy are also necessary (Kothari et al., 2020). Supplementation of oral vitamin c has very rapidly effect against scurvy taking 300 mg of vitamin c twice in a day is currently recommended and it continue at least our health and serum level show that



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our body has replenished its store(Roy-Lavallee et al., 2020).Vitamin c recommended is 0.25mg/dl for scurvy.its measure correctly in urine and serum. high dose around 1g are used for scurvy treatment(Essien et al., 2022).After taking vitamin c patient feel immediate improvement and oral symptoms improved within 6 days but ecchymes and bones abnormalities take some weak to recover and may be it take 2-3 month(Kothari et al., 2020)

Vitamin c and Cancer

Many people are suffering from cancer and he is became a first and second cause of death in the world and day by day cancer patient is increasing both physically, economically and developing, omit cancer drug became important need(Chen et al., 2022).Cameron and Pauling conducted some trials in which they treated 10g per day for next 10days result its very beneficial and after mayo clinic performed two randomised double blind clinic trial in which patient with advance cancer around 10g per day but both study have no benefit from high dose of vitamin c therapy(Yue & Rao, 2020).Several study suggested that venous administration of high intake of vitamin c is effective in cancer patient. Due to provident impact which promote apoptic death cancer cell in tumours periphery stimulating angiogenesis and spread. Some study show low millimetre doses range of pharmacological vitamin c eliminate tumours in vitro and decrease the risk of cancer formation in vivo. In reality there are several routines through which vitamin c influence cancer progression(Mussa et al., 2022).It is still unknown that how this nutrient particularly after more than 50year of study on function .In 1970s Ewan Cameron expanded on McCormick idea he proposed that vitamin inhibited the hyaluronidase which is help to reduce damage tissue and cell growth of cancer(Roa, et al., 2020).Study found those who have higher plasma level of vitamin c or consume vitamin c is reduce the risk of cancer .vitamin c intake is good indicator of taking fruits and vegetable many function of vitamin c in our body in various anticancer mechanism. Taking large dose of vitamin c than typical dietary intake and many physician recommended lager dose of vitamin c for prevention of cancer patient (Carr & Lykkesfeldt,2021) there are many study show that milimolarintake of pharmacological vitamin c successful to kill cancer cells as well as tumour development some cancer because sensitive against vitamin c and normal cell continue to became resistance(Carr & Cook, 2018). In 1950,vitamin c use for cancer treatment was initially explain the role of collagen synthesis to hypothesis that ascorbate replenishment is help in protect a normal cell. again metastatis as well as cancer development of supplementation of vitamin c is help improve our immune system(Codini, 2020)

In 1969, cancer cell was mentined ,large amount of vitamin c might be prooxidant effect on cancer cell .yun said formation of h2o2 is the main cause of destroying the cancer cell and produce very less antioxidant enzymes such as catalase, superoxide dimustase and glutathione peroxidase as compared to any other normal cell(Carità et al., 2020). Many author are fear to recommended the dose of vitamin c for treatment because of antioxidant property and it's accumulate in tumour and some another think different they think high dose of vitamin c supplementation not interfere with any therapy and it will be increase. Clinical study show there is no between effectiveness of chemotherapy medicine and antioxidant drug(Codini, 2020).Study show that the ability of vitamin c to kill many types of cancer cell and some study show that combination of high dose of vitamin c with conventional and anti drug increase cytotoxicity in many cancer cell(Bedhiafi et al.,2022).large dose of vitamin c cause cytotoxicity in our body which is may be harmful. Many researcher show that high intake of vitamin c cause ROS buildup as a result immunogenic cell death. Some reacher investigator that the high intake of vitamin c and ICT with combination(Fan et al., 2023). Few studies claim that high dose of vitamin c help to reduce the risk of pancreatic cancer and some other types of cancer (Visser &Das, 2018). Fewstudy show that vitamin c can kill cancer patient, in cancer patient common to have low plasma concentration of ascorbate then healthy person and vitamin c deficiency can relate with increased the cancer risk, cancer cell are high in oxidative stress than a normal cells (Ngo et al., 2019). Cancer patient found that have lower plasma level of vitamin c as compared to healthy person .Some study claim that high dose of vitamin c is not helpful for cancer patient. Vitamin c important for our well-functioning of immune and epithelial barrier cell. In many people are suffering from infection because of low intake of vitamin c (Doseděl et al., 2021).In pre-clinical studies we clearly show that vitamin c is very important role in our normal immune functionally and manufacture of immune cells for ex- natural killer cells and T-lymphocytes which are fight against cancer cell in infection (Van Gorkom et al., 2019). In 1970; s Linus Pauling already develop a strategy to use intravenous vitamin c in cancer patient, this method treat many patient in advance cancer. Patient recommended high dose of vitamin c. (Magri, et



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al., 2020). In recent result there is no evidence both human and animal, studies claim that there is no clear evidence of antioxidant reduce the risk of cancer (Ngo et al., 2019). Many cancer patient found that have lower plasma level of vitamin c as compared to healthy person. Some study claim that high dose of vitamin c is not prevent from cancer (Van Gorkom et al., 2019). Many researchers show that large dose of vitamin c can boost our immune system during winter. vitamin c supplement is very beneficial remedy to prevent from infection (Cerullo et al., 2020). During winter taking of vitamin c help to reduce the risk of tiredness and boost our immune system.

Vitamin c and Covid-19

Corona virus disease 2019(covid) main caused is SARS-COV2 corona virus. In world more than 100 million people are infected (Milani et al., 2021). Vitamin c is mostly used for treatment of respiratory infection. Vitamin c first used by early 1930s and 1970s after Linus Pauling found that it can treat common cold but many evidence unable to show the benefit for to treat respiratory infection (Hemilä & Chalker, 2013). In many study show that vitamin reduced the vasopressor, mortality and organ damage of sepsis patient (Rawat et al., 2021). High dose of vitamin c is very effective against sepsis and septic shock (Bae & Kim, 2020). Intake of vitamin c everyday help you to get over a flu but doesn't effective for who are involve in intense physical activity for example long distance race, skin. vitamin c supplement take once and show any benefit. people are very interested in wheather or not vitamin c for used to treatment of covid-19 because of may be have antiviral effect (Simonson, 2020). Vitamin c and some othere medicine such as corticosteroid as well as thiamine help to stop organs from getting worse and reduce the risk of sepsis and septic shock (Feyaerts, 2020). Vitamin c contain antioxidant, antithrombotic and anti inflammatory function and at reduce swelling, prevent from blood clotting as well as immune system (Pedrosa, 2022). Vitamin c is used in very widely in the world because of its safe, effective and inexpensive treatment. it boost our immune system function such as enhance the level of phagocytes, lymphocytes and improve T lymphocyte too (Hemilä & Chalker, 2013). No evidence yet that except vitamin c no can increase our immune system or help to protect from any types of virus. if a person follow healthy diet everyday it can be provided a strong immune system that can fight against any types of viral attack (Hemilä & Chalker, 2013). Globally confirmed that covid-19 pandemic which is caused by SARS-COV-2 infection. no effective treatment found yet for prevention of covid-19. some numerous research study show that large dose of vitamin c help in treatment of lung injury due to various type of inflammatory illness and lower the death rate and improve condition of oxygen support experience covid-19 patient (Gao, 2021). Vitamin c contain antioxidant, anti-inflammatory, immune-modulating are characteristics are processed for vitamin c. Important role of vitamin c in down regulation of cytokines for endothelium protection from oxidative damage during covid -19 if tested for effective and safe for many clinical trials (Rs et al., 2022). Function of vitamin c in covid-19 and pneumonia is the first mandolin randomization research. In data revealed that circulating level of vitamin c are not linked to covid-19 infection or pneumonia (Hui et al., 2022). Some study show that vitamin c, prophylaxis and progress. some few study claim use of vitamin c treat covid-19 (Rs et al., 2022).

Vitamin c and anemia

Vitamin c production of haemoglobin for fast recovery of anemia. orange contain good sources of nutrient especially in vitamin c and bioflavonoid. which role in important for stop the bleeding, increase the physical and mental decline. Vitamin c help to boost absorbic ferroin iron (Novelia et al., 2020). Anaemia it can happen when enough blood is not in your body. haemoglobin stimulate in blood to carry oxygen in the cell. some common symptom are difficult in breathing, headache, irregular heartbeat, pain on chest (Bhadra and Deb, 2020). A previous study found that relation between vitamin c and haemoglobin and later auther claim that there was no linked between iron and vitamin c. orange is block their iron absorption as well as haemoglobin level. its hoped that anemia will be decrease (Novelia et al., 2020). Some food in anemia patient must be added in our diet such as red meat, fish, egg, darkgreen vegetable, to fu, and all type of citrus fruits. are also rich in vitamin c which are help to treat anemia as soon as possible (Bhadra and Deb, 2020). Recommended dose of vitamin c is high because of its absorption of iron and this is very effective method for pregnant women anemia. intake of iron tablets everyday and vitamin c rich food, green vegetable everyday and anemia pregnant mother must be avoided drinking coffee or tea when she is not have enough vitamin c in her body and 50mg of vitamin c give in everybody (Gusmaliza, 2022). Vitamin c show that proper iron apsrption is gastroint estional tract and extra iron preparation are often found. vitamin c contain high





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amount of antioxidant(Wiciński et al., 2020) Vitamin c is vital component and our body require for the creating red blood cells. It inhibit the growth of hemosiderin which is very difficult to movement for iron realeasing when its needed. vitamin c eaten in our diet give acidic atmosphere the reduction of ferric acid into ferrous iron which is absorbed by own small intestine is very easy(Elba et al.,2021) Vitamin c improve non-heme iron absorption and the mechanism behind this effect is not yet known(Gupta et al., 2020).This study was investigated that show a good amount of iron and vitamin c intake help in iron development especially in older patient.those patient which are consume below then 50% of RDA cause the high of developing anemia(Rahfiludin et al., 2021).Vitamin c ability to absorption of iron was not used since and meet combined with food who content iron in same meal(Wiciński et al., 2020).Iron deficient patient should learn about which food contain a good amount of iron. Some sources are red meat, raisin ,dates, to fu and green leafy vegetable.vitamin c help in iron absorption(Turner et al., 2022).Vitamin c contain plant boost our bioavailability suggested that 250mg of vitamin c dosage for enhance the gastro intestinal absorption of iron and also increase the speed of erythropoiesis as a result it easy to digest by bone marrow(Wiciński et al., 2020). High dose of vitamin c around 10mg per day. They are found very few side effects.there are found in only few side effects. There are linked between high intake of vitamin c and theseside effect not clearly seen yet and explain 10mg per day in adult(Juneja et al., 2022)

Vitamin c and Obesity

In globally the obesity patient is more than triple more than triple in adult in the 1970,s increase both in children and adolescent(Blühe et al.,2020).Vitamin c deficiency is mostly found in obese people because antioxidant reduce the oxidative stress. Vitamin c prevent from free radical and lastely Johnston discovered the negative relation between plasma content as waist circumference and BMI(Lapik et al., 2020).Vitamin c very negative effect when a person body weight higher multiple epidemiological relation between plasma ascorbate concentration and body weight .mostly global recommended for adult for vitamin c intake increasing cases of obese in all over world (Carr et al., 2022). Advantage of vitamin c, multifunctional molecule oxidative stress protected by vitamin or relieving inflammation and some other health beneficial need special attention(Marks et al.,2021) Levine pharmacokinetic study used to require concentration the potential intake of vitamin c for higher body weight to reach vitamin c status as compared to individual ingestivity of a good amount of vitamin c(Carr et al., 2022).Vitamin c fruits are found they have antiobesity properly which can reduce our body weight and adipocyte number reasearcher show that some infant who formula fed and bottle fed are the risk of vitamin c deficiency and obesity too.vitamin c deficiency can be reversible if vegetable and fruits are available and consume everyday(Marks et al.,2021).

CONCLUSION

To put it simply, studies looking at how much vitamin c affect our health, disease and mortality. In this review paper we discussed about vitamin c for different disease but my own opinion is that make it hard to say that vitamin c is really effective for all disease. many cases vitamin c is not protect our body against some disease such as corona and covid-19 are not proven yet that is effective or not. Otherwise vitamin c is also beneficial against anemia, scurvy and obesity etc. Vitamin c is one of the important and necessary vitamin for our maintaince of all over body. numerous physiological process for human body and vitamin c dose depend on the basis of patient need for example if a person intake of alcohol and smoking on the daily basis so he need some extra vitamin c as compared to normal person intake. In future generation we all want to know that vitamin c effect clearly proven against covid-19 and cancer

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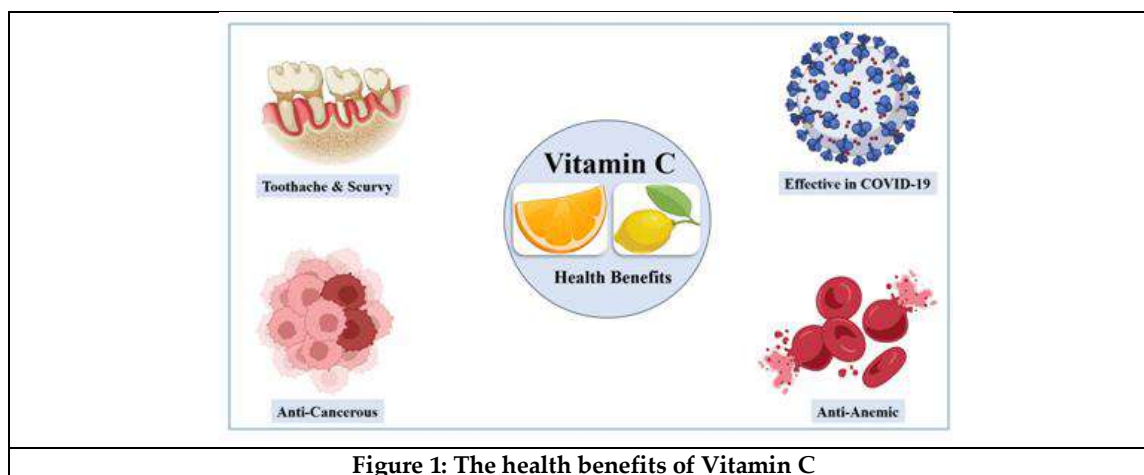


Figure 1: The health benefits of Vitamin C





Comparative Evaluation of Remaining Dentin Thickness and Time Required for GP Removal using Two Different Retreatment File Systems : An *In-vitro* Study

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ABSTRACT

The study aims to evaluate and compare remaining dentin thickness (RDT) after retreatment and time required for GP removal using two different retreatment file systems. 40 single rooted, non-carious, single canal permanent teeth were selected. The teeth were decoronated to obtain a standard length of 16 mm. Endodontic treatment was performed and obturation was done using single cone technique. Specimens were stored in saline at 37°C for 1 week. A CBCT scan was obtained in which Remaining Dentin Thickness (RDT) was measured for each sample at 3, 6 and 9 mm from the apex. The specimens were randomly divided into 2 groups (n=20) based on the retreatment file system used Group 1 – Style Italiano files and Group 2 – Neo-Endo files. Then while retreatment procedure was being performed the time required to remove the Gutta percha (GP) was measured using a stopwatch. After removal of GP, a CBCT scan was performed to measure the RDT post retreatment procedure. The data obtained were tabulated and evaluated using the Statistical Package for the Social Sciences (SPSS) software program. The results indicate that in terms of dentin removed there was statistically significant difference between the two groups at level 3 mm and 6 mm, whereas at level 9 mm, there was no statistically significant difference between the two groups. Also, statistically significant difference was found between the two groups in terms of time required for GP removal. The study concluded that in terms of Remaining Dentin Thickness, Style Italiano files preserved more dentin than Neo Endo group. Whereas, the time required for Gutta Percha removal was lesser in Neo Endo group.



**Mukund V Singh et al.,****Keywords:** Remaining Dentin Thickness, Retreatment, Gutta Percha, Neo-endo retreatment, Style Italiano retreatment, CBCT

INTRODUCTION

Root canal treatment, although generally successful, may sometimes fail to achieve the intended result.[1] Failures can occur even with the most careful procedures and adherence to best practices. [2] The primary causes of these failures are the continued presence of bacteria in the complex root canal system, often due to improper cleaning or filling, procedural errors, or the absence of an appropriate fluid-tight seal, allowing microorganisms to survive in dentinal tubules, apical ramifications, and accessory or secondary canals. [3] Modern techniques for removing root filling materials include the use of hand or rotary nickel-titanium (NiTi) instruments, sometimes with heat, solvents, or ultrasonic tools. Specialized rotary instruments designed specifically for retreatment, such as Neo-Endo and Style Italiano retreatment files, are now available. In non-surgical retreatments, maintaining the remaining dentin thickness is critical to avoid complications like excessive dentin removal or perforation. [4] Orthograde retreatment involves the removal of existing filling material, followed by debridement and then obturation. In addition to removal of the old filling material, it is of great significance for the operator to conserve the remaining tooth structure to improve the long-term success of the treated tooth.[5] Neo-Endo retreatment files (Orikam Healthcare, India) feature advanced heat treatment and micro grinding manufacturing techniques to reduce the engagement zone. These files possess controlled memory along with a parallelogram cross-section, and a positive cutting tip which help to prevent ledge formation and file breakage during retreatment.[6] Style Italiano retreatment files (Style Italiano, Italy) are designed to remove gutta-percha in a minimally invasive manner and utilize heat treatment technology and is a set of five files. Style Italiano retreatment files have lesser taper to ensure a better outcome and to reduce further complications like stripping, zipping of the apex and alteration of the original anatomy. Cone-beam computed tomography (CBCT) is frequently used in endodontics and is more effective than traditional radiographs for detecting periapical pathologies and root resorption. It is also superior for assessing root canal morphology and guiding endodontic surgery. [7] With the aim of preserving the remaining dentin thickness, this study aimed to evaluate the RDT using two different retreatment instruments through CBCT and the time taken by these systems for removal of gutta percha.

MATERIALS AND METHODS

Sample Preparation

For this study, forty freshly extracted single-rooted permanent teeth were chosen. Teeth that exhibited additional canals, fractures, significant canal curvature, or signs of internal and external resorption, as identified through radiographic evaluation, were excluded. The selected teeth were carefully cleaned to remove any tissue remnants and debris using a scaler, disinfected in 5.25% sodium hypochlorite for one hour, and then stored in saline for later use. The teeth were then decoronated using a diamond disk, and the length of each tooth was standardized to 16 mm.

Root Canal Preparation

After creating an access cavity in each tooth with a high-speed handpiece and a No. 2 round bur (Mani) with air-water spray, a #10 stainless steel K-file (Mani) was inserted into the root canal, and the working length was measured using RVG. The root canals were shaped using Hero Gold rotary files (Micro Mega, France) with the crown-down technique, up to size #30 and a 0.06 taper. Canal irrigation was carried out with 3% sodium hypochlorite, saline, and 17% ethylenediaminetetra acetic acid (EDTA). The canals were dried using paper points and filled with gutta-percha points of the appropriate size and taper, along with AH Plus resin-based sealer (Dentsply De Trey, Konstanz,



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Germany). Cavit G was placed to temporarily seal the teeth, which were then stored at 37°C and 100% humidity for one week to allow the sealer to fully set. Following this, the samples underwent pre-operative CBCT scan.

CBCT Scanning and Evaluation

The samples were placed on a wax mold to maintain consistent positioning. The remaining dentin thickness was calculated by measuring the shortest distance from the edge of the uninstrumented samples to the root margin. These measurements were then compared with those obtained from the scans of the instrumented samples at 3 mm, 6 mm, and 9 mm from the apex. The average dentin removed at these levels for both groups was calculated using the formula: $\text{MD1} - \text{MD2}$, where MD1 is calculated as $m1 + d1/2$ and MD2 as $m2 + d2/2$. In this formula, m1 and d1 represent the shortest distances from the mesial and distal edges of the root to the corresponding edges of the filled canal, while m2 and d2 represent the shortest distances from the mesial and distal edges of the root to the corresponding edges of the canal after gutta-percha retrieval.

Retreatment Procedure

Twenty samples of teeth were randomly assigned to each of the two experimental groups. Group 1 – Neo-Endo retreatment files: Gutta-percha removal from the coronal third of the root canal was done using the N1 file (30/09), from the middle third using the N2 file (25/08), and from the apical third with the N3 file (20/07).

Group 2 – Style Italiano retreatment files

Gutta percha was removed from the coronal third of root canal using Bull-Y file (25/07), from the middle third using Skinn-Y (24/04), and from the apical third using Shap-Y1 (20/05) All rotary files were used according to the manufacturer's instructions. Irrigation was performed using 3% sodium hypochlorite. When there was no visible gutta percha residue left on the instrument, retreatment was deemed to be complete. To evaluate the effectiveness of the retreatment preparation, digital radiographs were taken to check for any traces of the obturating material or sealer left in the canals. The time taken for the gutta-percha removal process was recorded using a stopwatch, and the amount of remaining gutta-percha was assessed using conventional radiographs. Post the gutta-percha removal, the root canal irrigation was done for three minutes with 3mL of 17% EDTA followed by saline rinse, and then dried with absorbent paper points.

Statistical Analysis

Statistical analysis was done using descriptive statistics. Paired t-test was employed to compare the pre and post mean RDT of all samples in both groups. Unpaired t-test was applied to compare mean RDT in both groups. One way ANOVA was used to compare the means of both the study groups. An independent t-test was performed to evaluate the time taken by each group to retrieve gutta percha. Statistical software namely SPSS version 21 was used to analyze the data. p-value of less than 0.05 was considered to be statistically significant.

RESULTS

At level 3 mm and 6 mm, there was statistically significant difference between the two groups. At level 9 mm, there was no statistically significant difference between the two groups. Table 2 and Figure 2 represents the mean and standard deviation for the time taken for gutta percha retrieval using the two file systems Neo Endo and Style Italiano. Statistically significant difference is found between these two groups.

DISCUSSION

There are several factors that can contribute to endodontic failure, including incomplete cleaning, incomplete obturation, and missed canals which may result in retreatment. [8] Endodontic retreatment is largely replacing endodontic surgery as the preferred approach for resolving persistent periapical infections since it is less invasive.[9] Numerous studies have been conducted in the past to compare the efficacy of various file systems in removing



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obturator material. [10] These studies followed specific protocols, such as the use of chemical solvents to remove gutta-percha, and two-dimensional digital radiography to confirm the complete elimination of the filling material. [11] The study did not use solvents, as previous research has indicated that their use can lead to inaccurate results by leaving significant amounts of endodontic material and sealer on the canal walls during retreatment procedures. [12] Furthermore, the use of solvents can aggravate periapical tissues, making it harder to accurately determine the retrieval time, as noted in previous studies. [13] Various techniques, including conventional radiographs, microcomputed CT, CBCT, and longitudinal sectioning, are recommended for assessing remaining obturator material during endodontic retreatment. [14,15] In this study, CBCT was employed to evaluate the complete removal of the filling material. The time for gutta-percha retrieval was recorded using a stopwatch. Rotary instruments are typically favored over hand instruments in retreatment procedures as they generate friction that softens the gutta-percha, making it easier to remove. Additionally, rotary instruments help reduce operator fatigue, shorten working time, and preserve the canal's shape. [16] The study identified a statistically significant difference in remaining dentin thickness between the Neo-Endo and Style Italiano retreatment groups, which can be attributed to two factors: the taper variation between the instruments and the heat treatment of the Neo-Endo files, whereas only the Bull-Y (25/07) and Shap-Y1 (20/05) files from Style Italiano were heat-treated. The heat treatment of Neo-Endo retreatment files enhances their flexibility. Additionally, the smaller taper of Style Italiano files helps preserve dentin and reduces the risk of canal transportation. Further research is needed to include a variety of retreatment file systems, posterior teeth, curved canals, and more advanced imaging techniques like micro-CT to support and expand upon these findings.

CONCLUSION

Within the limitations of the study, we can conclude that in terms of time required for gutta percha removal, the Style Italiano retreatment files took longer time but preserved more dentin than the Neo-Endo retreatment files which took lesser time for gutta percha removal and resulted in lesser remaining dentin thickness compared to the Style Italiano retreatment files group.

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Table 1: Representing the mean and standard deviation values of the dentin removed for both the groups at 3 mm, 6 mm and 9 mm respectively.

Levels	Neo-Endo retreatment	Style Italiano retreatment	P - value
3 mm	1.31 ± 0.39	1.42 ± 0.35	< 0.05
6 mm	1.26 ± 0.42	1.37 ± 0.47	< 0.05
9 mm	0.97 ± 0.26	1.02 ± 0.19	> 0.05

Table 2: Representing the mean and standard deviation for the time taken for gutta percha retrieval using the two file systems Neo Endo and Style Italiano.

Group	Mean ± Standard Deviation	P-value
Neo-Endo retreatment	3.28 ± 1.02	< 0.05
Style Italiano retreatment	7.01 ± 1.57	< 0.05



Fig 1: Single rooted sample teeth



Fig 2: Samples arranged on wax mold





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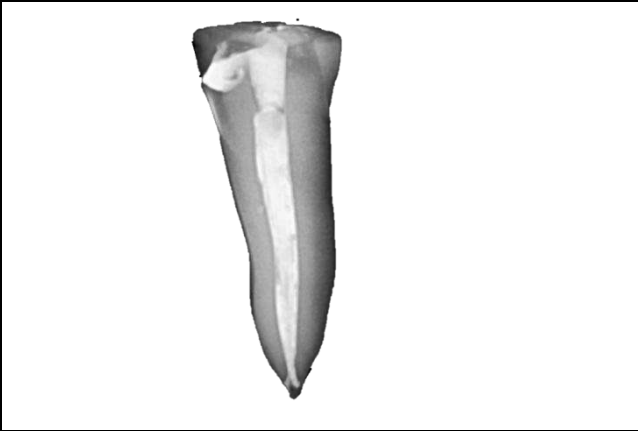


Fig 3: Obturated sample

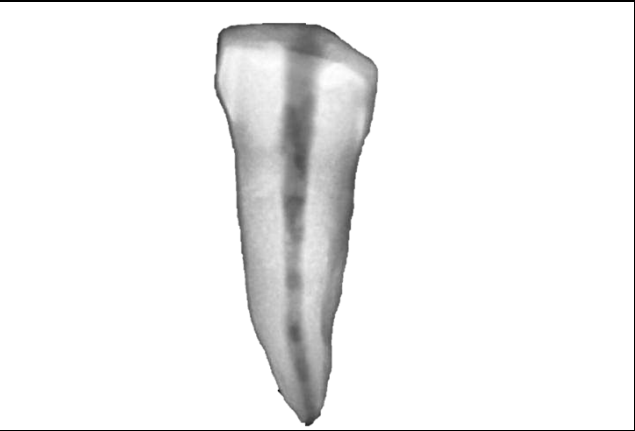


Fig 4: Retreated sample



Fig 5: CBCT of sample after retreatment using Neo-Endo retreatment files



Fig 6: CBCT of sample after retreatment using Style Italiano retreatment files

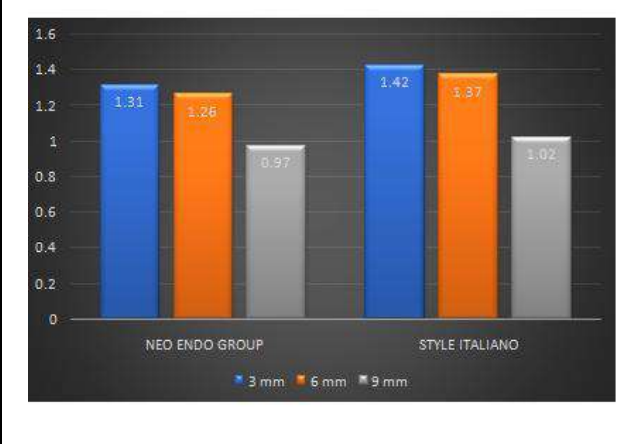


Fig 7: Representing the mean and standard deviation values of the dentin removed for both the groups at 3 mm, 6 mm and 9 mm respectively.

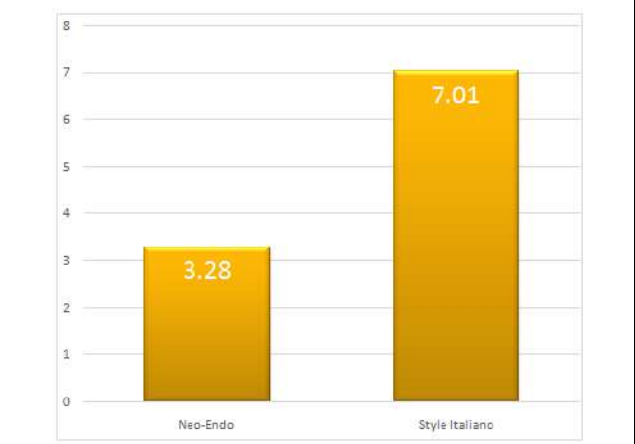


Fig 8: Representing the mean and standard deviation for the time taken for gutta percha retrieval using the two file systems Neo Endo and Style Italiano.





Survey on Deep Learning based Tampering Detection Techniques for Secure Image Manipulation

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ABSTRACT

Image tampering, a critical issue in the digital age, poses significant challenges to the authenticity and integrity of visual data. This comprehensive survey explores various image tampering localization techniques, tracing their evolution from traditional methods to advanced deep learning approaches. This paper categorizes these techniques into four main groups: block-based, keypoint-based, deep learning-based, and hybrid methods. Each category is meticulously examined, highlighting key methodologies, their advantages, and limitations. Furthermore, this survey analyzes the trends in the field, emphasizing the shift towards more sophisticated and robust deep learning frameworks that offer improved accuracy and reliability. Additionally, the survey addresses the challenges faced by current techniques, such as the need for large annotated datasets and the high computational costs. Finally, we propose future research directions, advocating for the integration of multi-modal data, the development of real-time tampering detection systems, and the exploration of unsupervised learning techniques to enhance the efficacy and applicability of image tampering localization methods. This survey aims to provide a comprehensive reference for researchers and practitioners, facilitating further advancements in the domain of image forensics.

Keywords: Image tampering, Deep learning, Restoration, SIFT, SURF.





INTRODUCTION

Digital pictures are ubiquitous in our everyday lives, serving as key carriers of information transfer. As image processing technology has advanced, several picture editing tools have made it easy to produce realistically altered images [1][2][3]. A cascade of unfavourable outcomes is inevitable whenever altered photos are used for malevolent objectives, including fabricating certifications or spreading rumours [4][5][6]. Consequently, identifying manipulated photos is crucial for preventing their exploitation. Forensic techniques to identify altered photos and pinpoint their exact locations have proliferated in recent years [7][8]. A shift from using hand-crafted features to deep learning approaches has been seen in the technical paradigms of these methods [9]. These days, forensic techniques based on deep learning outperform their more traditional counterparts [10]. The use of efficient network topologies, including fully convolutional networks, U-Net, faster R-CNN, mask R-CNN, and ViT, is one possible explanation. Also, forensics relies heavily on a mix of deep learning and domain expertise [11][12]. In order to detect any changes done after capture, image tampering localization seeks to locate and identify changed areas within a picture [13]. When faced with the variety and complexity of manipulation techniques, traditional methods that depend on heuristic and statistical approaches often fail [14][15]. There has been a lot of development in the area since the introduction of machine learning and, more newly, deep learning; new approaches provide better detection accuracy and resilience [16][17]. This review summarises the current status of the art in localising image manipulation [18],[19]. In this survey classifies the current methods according to their underlying architecture: block-based, keypoint-based, deep learning-based, and hybrid approaches [20][21]. There is an in-depth analysis of each grouping, with a focus on the fundamental ideas, advantages, and disadvantages of each. The goal of this study is analysing these approaches to find out what's happening now and where the research in this important field is heading [22]. Additionally, we tackle the typical issues encountered by existing tampering localization methods, including the need of big, annotated datasets, significant computing loads, and the capacity for processing in real-time [23][24]. In this work lays the groundwork for future study by highlighting these obstacles; the propose investigating unsupervised learning methods, improving algorithm efficiency and effectiveness, and integrating multi-modal data [25]. The paper is organized as follows. In Section 2, Background of the study was discussed. An existing methods image restoration and tampering localization methods are discussed in section 3. Section 4 shows the Discussion and Finally section 5 gives the conclusion of this paper.

Background study

Akhtar, N. et al. [1] the field of digital video forensics was very new, and the validity of digital footage as evidence in legal proceedings was uncertain because of the possibility of manipulation (forgery). Any number of video editing programmes, including Adobe's, GNU Gimp, Premier, and Vegas, were easily accessible for use in such endeavours. The research issues that guided this effort were addressed in this study, which included a thorough assessment of methods for detecting digital video forgeries. Bhalerao, S. et al. [2] since the advent of digital communication, the safety of multimedia communications has risen to the forefront of people's minds. Consequently, this study suggests a delicate and safe method of picture watermarking for the purpose of detecting image tampering. A SHA-1 hashing algorithm-based block-based watermarking method was suggested. Cao, G. et al. [3] to test how well state-of-the-art image tampering localization methods protect against intrusion, the author provide an adversarial assault approach. Following a formal formulation of the attack on tampering localizers, unified attack architecture was used to demonstrate two adversarial example techniques of attack. In both white-box and black-box situations, these authors suggested assaults considerably lower the accuracy of state-of-the-art tampering localizers. Diallo, B. et al. [4] the author present a deep learning architecture that can reliably identify cameras and detect instances of manipulation in images. It encompasses all the usual picture alterations that users employ while sharing photographs. By manipulating the compression quality factor, the author evaluate these authors system and demonstrate that it outperforms methods found in the literature on a global scale. Guo, K. et al. [5] the author provide a new method for localising instances of picture manipulation that makes use of co-attention feature fusion and a two-branch improved transformer encoder. The author uses the feature improvement module to make the network representation stronger, and the author use the coordinate attention-based fusion module to integrate the features from different scales. Hao,



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J. et al. [6] to simulate global context and all pairwise interactions between patches at various sizes, the author introduce TransForensics, which employs dense self-attention encoders. This study was ground breaking because it applies transformer self-attention techniques to the problem of identifying and localising altered areas. Jena, R. et al. [7] the author presented a privacy-preserving system for encrypted JPEG picture tamper detection in this study. Combining two JPEG photos of varying quality was likely to result in forgery detection, according to these authors research. One of the initial minima in the energy graph was the featured image's quality. When the JPEG quality remains constant, however, the likelihood of detecting forgeries was minimal. Joshi, V., & Jain, S. [8] Digital movies may be efficiently feature extracted using the suggested approach, which was both robust and compact. These characteristics were retrieved from digital video clips that portray a video segment with both spatial and temporal information. The suggested method can identify and pinpoint the edited area in a digital video. Laouamer, L., & Tayan, O. [9] an effective spatial-domain non-blind watermarking method was presented in this work, and its tamper-localization accuracy and image-recovery quality were shown to be exceptional. These authors robust watermarking system incorporates linear interpolation to improve performance during watermark picture extraction; this improvement allows these authors approach to provide complete detection and recovery capabilities, which was a noteworthy contribution/novelty of this study. Li, D. et al. [10] the author provide a new approach to localising image fraud using a two-stage edge-aware regional message passing control mechanism. In particular, making preparations to make maximum use of the edge information was the first stage.

Second, an edge-aware dynamic graph was constructed to reduce the strength of the message flowing between the genuine and forged areas, led by the learnable edges. In order to address the issue of misjudgement in IFL, these authors work presents a novel research approach. Rao, Y., & Ni, J. [12] these authors research proposes a self-supervised domain adaptation network (ComNet) for JPEG-resistant picture fraud localization. The network combines a backbone network with a compression approximation network. The author do away with data augmentation using genuine JPEG compressed pictures and instead use ComNet, trained with self-supervised learning, to approximate the JPEG compression procedure, and produce JPEG-agent images. Saju, G., & Sreenimol, K. R. [13] to attain high levels of authenticity and integrity, these authors algorithm has been suggested. If someone tampers with a digital document picture, these authors method can find it and pinpoint where. Misdiagnosis could result from even a little amount of manipulation, such as a thin line. Insurers may lose a lot of money if this kind of manipulation occurs. This condition was well-suited to the discrete wavelet transform approach. The tuple-nature of the hash function allows it to pinpoint the precise location of the tampering. Salim, M. et al. [14] the author presented a method in this research that uses a visual cryptography watermarking system to identify and pinpoint picture forgeries. To ensure this method was effective and resilient, it was tested on the SIPI dataset and the CASIA V 1.0 dataset. The digitally altered photos in these datasets were subjected to a number of well-known assaults, such as compression, noise (both Gaussian and Speckle), sharpening, median filtering, scaling, rotation, and salt & pepper. Shaik, A. et al. [15] the author provide a method for perceptual picture hashing that makes use of ring partition and CSLBP. After the picture was transformed into a standard image, CSLBP was used to extract ring-based statistical information. These characteristics were fixed and do not change with rotation.

Since the ring partition has no effect on picture rotation, this was achieved. In comparison to previous methods, the findings demonstrate that the suggested hashing algorithm was more resilient and discriminative, and it can withstand geometric manipulations (such as rotation) applied to pictures. Shaik, A. et al. [16] these authors' research presents a method for picture hashing that utilises LWT and DCT. Tampering localization was one area where the suggested approach excels above the blind geometric correction method. After conducting the experiment on a big database, the results showed that the technique suggested for dealing with CPOs was effective. Additionally, pinpointing tampering zones and good discriminative ability would be great. Wang, M. et al. [19] a wavelet-based Compression Representation Learning Network (CRL-Net) was used to guide a JPEG Compression-Aware Image Forgery Localization Network (CA-IFL), which was proposed in this research. The compression representations obtained by CRL-Net using its contrastive learning technique were quite similar to those of JPEG compression. Using the learned representations as a foundation, the author describes the CA-IFL, which can adaptably deal with fake pictures compressed using different JPEG quality factors. Yarlagadda, S. et al. [21] these authors suggested technique



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for detecting and localising satellite images forgeries was detailed in this publication. An autoencoder may be trained to acquire a compact representation of image patches derived from perfect satellite photos, which was the reasoning behind the suggested approach. A feature extractor for picture patches may thereafter be used with this autoencoder. Ying, Q. et al. [22] an innovative generative technique for picture self-recovery, Imuge+ was introduced in this study. It was impervious to image tampering. The author take the original photos and make them immune to tampering so that the author can pinpoint where the assaults occurred and restore the original material in the affected regions. The author use an INN architecture to build the invertible function for image immunisation and improve speed. Zhang, W. et al. [23] these authors research presented a new multi-scale fusion approach that uses PRNU to identify digital picture forgeries, such as copy-move and splicing. Instead of estimating PRNU correlations on overlapped patches like current sliding window-based algorithms do, the suggested algorithm directly segments the test image into irregular, nonoverlapping blocks of multiple scales and calculates correlations on nonoverlapped segmentation patches. Zhang, X. et al. [24] here the author introduce EditGuard, the first effort at designing a deep adaptable watermarking method. Decoding correct copyright information and tampered regions, as well as integrating invisible localization and copyright watermarks, makes it a trustworthy tool for creative production and legal forensic investigation, adding credibility to photos. Zhu, H. et al. [25] through the exploration of pictures' general inherent properties, the author provide a new method for localising instances of image manipulation. The ConvNeXt encoder will extract characteristics that indicate hierarchical manipulation. Zhuang, P. et al. [26] the author provides ReLoc, a restoration-assisted framework, to make tampered localization more resistant to post-processing. Two modules make up the ReLoc framework: one for restoring images and another for localising instances of manipulation. In order to retrieve evidence of manipulation from warped photos, the author uses the image restoration module.

Existing methodology

Figure 1 is describe the overview of this paper and it is combined with deep learning based methods and block and keypoint based method using CNN, SIFT and SURF algorithms.

Image Tampering Detection algorithms

Convolutional Neural Networks: CNNs' capacity to learn intricate patterns and attributes from data allows them to identify and localise manipulated areas with high accuracy. Convolutional neural networks (CNNs) are able to detect minor signs of manipulation because they collect hierarchical characteristics, starting with low-level edges and textures and progressing to high-level semantic data. Demerits of this algorithm is To get decent results from CNNs, you need a lot of labelled training data. It could be difficult and time-consuming to collect and mark such data in order to identify manipulation. Not all applications may be able to handle the computational expense of training convolutional neural networks (CNNs). Generative Adversarial Networks: In order to detect small differences caused by manipulation, GANs may learn complicated, high-dimensional distributions of actual pictures. Demerits of this algorithm is essential to carefully balance the generator and discriminator networks while training a GAN, and the networks themselves are infamously tough to train. It is important to fine-tune training to avoid instability and ensure convergence.

SIFT

SIFT characteristics are great for identifying manipulations that affect scale, rotation, and lighting since they are resistant to these changes. In order to help localise manipulated areas, SIFT finds unique and repeatable keypoints and descriptors across many pictures. Demerits of this algorithm is It may not be feasible to use SIFT for real-time applications or big datasets due to the computationally demanding procedures involved, such as keypoint identification, descriptor calculation, and matching.

SURF

With its quicker architecture compared to its predecessor SIFT, SURF is more suited for real-time applications and efficient processing of huge datasets. Reliable recognition of keypoints and descriptors is assured using SURF features, which are resilient to picture noise. The accuracy of tamper detection, particularly in cases involving



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sophisticated picture alterations, may be affected by the fact that SURF, in comparison to SIFT, may not yield as unique features in some instances. Similar to SIFT, SURF is mainly designed to identify simple geometric changes like scaling, rotation, and translation. It could have trouble detecting more complicated forms of manipulation, such as content modification or sophisticated counterfeiting.

Convolutional Neural Networks

Because of their hierarchical feature extraction capabilities, Convolutional Neural Networks (CNNs) identify complicated patterns suggestive of tampering, such as structural abnormalities and texture inconsistencies, and picture tampering categorization is one area where CNNs really shine. By employing convolutional layers to capture local visual cues and pooling layers to minimise dimensionality while maintaining critical information, CNNs can successfully discern between tampered and real photos. Convolutional neural networks (CNNs) improve end-to-end to learn discriminative features and decision boundaries, guaranteeing excellent accuracy in classification tasks. CNNs are trained via supervised learning on labelled datasets. Despite the computational costs and possible interpretability issues, convolutional neural networks (CNNs) continue to play a crucial role in forensic analysis. They can identify different types of image manipulation by not only categorising manipulated areas but also localising them within pictures

Generative Adversarial Networks

A novel architecture called a Generative Adversarial Network (GAN) uses a competitive game between two neural networks, the discriminator and the generator, to improve the production of realistic data. Image tampering is an area where GANs really shine. These networks can generate fake but convincing pictures by manipulating the original, and then they use a discriminator to tell the difference between the two. This method uses adversarial training to fine-tune detection sensitivity, making GANs very good at identifying small tampering artefacts like colour or texture irregularities. Reliable tampering detection findings need careful tuning and robust data preparation since GANs encounters problems such training instability, mode collapse, and high computing costs. Notwithstanding these obstacles, GANs have great promise as instruments for sophisticated forensic analysis and systems for detecting manipulation due to their capacity to produce and distinguish realistic pictures.

DISCUSSION

Thanks to advancements in deep learning that provide more accurate and resilient localization of picture manipulation. While keypoint and block-based approaches have provided a solid foundation, they now confront obstacles including high computing costs and diminished efficacy in low-texture areas. Although they need massive computer resources and massively annotated datasets, deep learning methods have utterly transformed the industry. Combining deep learning techniques into hybrid methods has great potential for achieving a happy medium between promptness and accuracy. Challenges in dataset availability, processing costs, generalizability, and resistance to adversarial assaults continue, while current trends emphasise the development of real-time detection systems and increasingly advanced neural network designs. To improve the effectiveness and practicality of image tampering localization methods, future studies should inspect ways to fit in multi-modal data, enhance models for real-time processing, investigate unsupervised learning as a means to lessen reliance on labelled data, and strengthen models against adversarial manipulations.

CONCLUSION

In order to guarantee the genuineness and validity of digital visual data, the area of image tampering localization is vital and ever-evolving. With this all-encompassing review, have followed the development of localization techniques from their earliest iterations to modern deep learning and hybrid techniques. Although there are still issues with processing needs and data requirements, deep learning has brought exceptional resilience and accuracy, building on top of older approaches. Advancements in the discipline are seen in the growing trend of real-time





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detection and the creation of complex neural network structures. Big annotated datasets are necessary, but lot of obstacles to overcome, such as high computing costs, problems with generalizability, and exposure to adversarial assaults. A multi-pronged strategy including optimisation for real-time applications, research of unsupervised learning approaches, integration of multi-modal data, and enhancement. In order to ensure that digital images can be trusted in an increasingly digital environment, researchers should concentrate on these future paths to improve image tampering localization techniques.

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Table 1: Survey of Image Tampering Localization Techniques

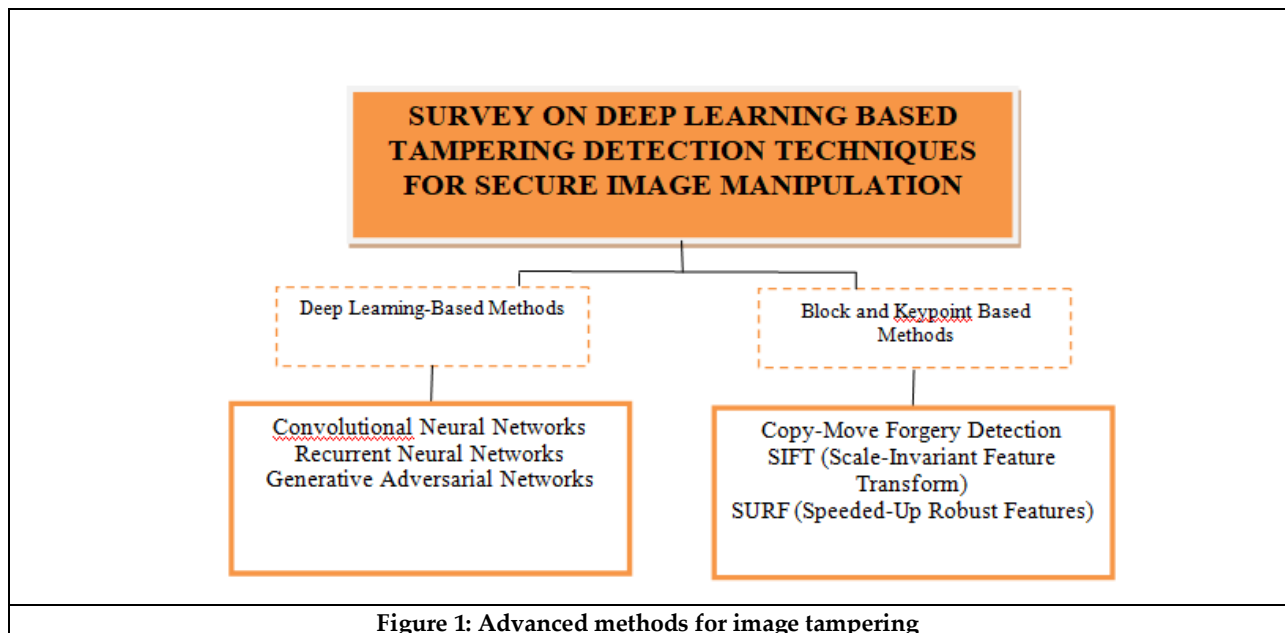
S.No	Author	Year	Methodology	Advantage	Disadvantage
1	Diallo et al.	2019	Robustness of image tampering detection for compression	Focus on improving detection under image compression artifacts	Limitations in handling complex tampering scenarios
2	Joshi V	2020	Adjacent frames of actual and reconstructed video clips	Very accurate for more than 7s in length or more than 200 frames.	Low performance with short video clips
3	Bhalerao et al.	2021	Secure image watermarking for tamper detection	Integration of watermarking for enhanced tamper detection	Dependency on robust watermark embedding methods
4	Akhtar et al.	2022	Digital video tampering detection and localization	Comprehensive review and algorithm exploration	Challenges in real-time application due to computational demands





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5	Abdul S. Shaik	2023	Authentication and Tampered Localization using Image Hashing	Robustness against brightness and contrast adjustment	Challenges in composite tampering consequences
6	Cao et al.	2024	Transferable adversarial attack on image tampering localization	Adversarial techniques for robust tampering localization	Vulnerability to adversarial countermeasures
7	Guo et al.	2024	Effective image tampering localization via enhanced transformer and co-attention fusion	Enhanced deep learning models for precise localization	High computational costs and resource demands





Transdermal Drug Delivery System for Treatment of Hypertension

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ABSTRACT

The skin permeation therapy is the sustained and controlled drug delivery whose goal is to spread the drug via the skin at a specific and regulated rate and time. More prevalent disorders in the world today is hypertension. Although it is not a disease and of itself, it is a substantial risk element to cardiovascular morbidity and death. This article gives the efforts made to make and administer transdermal patches as a means of increasing the bioavailability of antihypertensive medications. The first transdermal antihypertensive medication created was clonidine. Many transdermal patches for hypertension are now being launched to the pharmaceutical market. For the manufacture of transdermal patches, solvent evaporation or solvent casting processes were used in the majority of documented methods in the literature. Polymer, plasticizer, and Atenolol administered by transdermal patch allows drug molecules to enter the bloodstream directly, circumventing the harsh gastrointestinal environment and first-pass metabolism that are frequently associated with oral delivery. Transdermal patches having atenolol were created utilizing the solvent evaporation method. Various proportions of Methacrylic acid copolymer (RL type), Ethylcellulose resin, and PVP were combined.

Keywords: Hypertension, Percutaneous absorption, Controlled release, Adhesion, Matrix film.





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INTRODUCTION

Drug administration through the skin has drawn more attention as a means of both systemic and topical drug delivery, as well as local therapeutic effects on skin. Compared to many other ways of drug incorporation, the skin offers a number of important advantages for drug delivery, such as the ability to prevent issues with pH and emptying rate effects, gastric irritation, and hepatic first-pass metabolism, which increases the drug's bioavailability, lower the risk of systemic side effects by minimizing serum level correlated to oral therapy, provide a localized pharmaceutical distribution place of application, enable rapid therapy termination by removing the device or formulation, and reduce fluctuations in plasma levels.(1) When it comes to the long-term management and prevention of long term conditions like hypertension, the TTS (Transdermal Therapeutic System) is especially clinically significant. Age-related increases in heart disease mortality are significant. (2) One of the primary factors that contributes to heart disease as well as the age-adjusted death rates from hypertension and heart disease in recent years have been going up 57 percent of cases are directly caused by hypertension. Fatalities from stroke and 24% of cases of coronary heart disease pass away in India. Combining Indian health data Studies reveal that 25% of people have hypertension. 10% of subjects were rural, 10% urban. Even though TDDS is a good option for treating long-term conditions including hypertension, the high expense of patches for hypertension rather than traditional goods (3)

History

The FDA approved, At 1979 motion sickness transdermal patches and it contained Scopolamine. In 1981, nitroglycerine was approved as the second patch. There is a wide range of transdermal application patches on the market. (4)

Advantages

1. This procedure is easy to use and just needs to be applied once a week. Such a basic dosage schedule can help patients follow their medication regimens.
2. Since transdermal distribution prevents side effect on the stomach and gastric area drug that disturb the digestive system is favourable for this mode of administration. Avoid gastrointestinal incompatibility.
3. Medication which degrades the stomach's acids and enzymes could potentially be a useful target. (5)
4. A consistent and long-lasting activity allows for the use of a medication with a brief biological half-life and a limited window for treatment. (6)

Disadvantages

1. The potential for localized irritation when the product is applied.
2. The medicine, bonding agent in the patch making may induce erythema, irritation, and local edema.
3. Could result in allergic responses.
4. 500 Da or less weight is necessary.(7)

STRUCTURE OF SKIN

Epidermis

The thickness of the multilayered epidermis varies from 0.9 mm on the grips and undersides of the feet to 0.05 mm on the eyelids, depending on the size and quantity of epidermal cell layers. Corneum stratum. This is the skin's outermost layer. When completely hydrated, it swells to several times its dry thickness of around 10 mm. It contains 10 to 25 layers of corneocytes, which are dead, keratinized cells. Although it is flexible, it is not very porous. The main obstacle to drug penetration is the horny layer. The keratinized cells in this model serve as protein "bricks" encased in lipid "mortar." The fats are organized lipid portion, including cholesterol and polar free fatty acids, to preserve a bilayer structure. Keratinized layer is covered by viable epidermis, which ranges in thickness from 0.05 mm on the eyelids to 0.9 mm on the palms. Consists of many membranes that go inward, including the stratum lucidum, granular layer, spinus layer, and the stratum basal. The epidermis at the basal layer is continuously renewed by cell mitosis, which makes up for the loss of dead horny cells from the skin's surface.





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Dermis

This is a layer that is 3 to 5 mm thick and is composed of a connective tissue matrix that includes nerves, lymph vessels, and blood vessels. The skin's blood supply plays a crucial regulatory function in anatomy temperature. The majority of molecules that penetrate the skin barrier find a sink state in capillaries, which extend to within 0.2 mm of the skin's surface.

Hypodermis

The true skin and cutaneous layer are supported by the hypodermis, or subcutaneous fat tissue. It acts as a place to store fat. This layer offers nutritional assistance, mechanical protection, and aids in temperature regulation. It transports the main blood vessels, nerves, and maybe sensory pressure organs to the skin. For drug to be penetrate transdermally, it must go by all three of these layers and reach the systemic circulation; for topical drug administration, just the stratum corneum must pass through before the drug is retained in membrane of skin.(8)

PERMEATION THROUGH SKIN

The most popular route for medication molecules to enter the body is the paracellular route. This mechanism keeps API in lipid moiety and close to the keratin (which makes it easier for lipid-soluble drugs to do so than proteins).

The transappendgeal route creates a continuous conduit for drug penetration, although it is readily impeded by the existence of sweat ducts and hair follicles.(9)

TRANSDERMAL PATCHES

Recent advancements have broadened its application to include the delivery of stimulants for Hyperactivity disorder, hormonal contraceptives, and even antidepressants. The FDA declared in 2005 that it was looking into reports of fatalities and other severe side effects associated with opiate overdose in patients taking Duragesic, a transdermal patch containing fentanyl, for pain relief. Later, in June 2005, the Duragesic product label was revised to include safety information. Transdermal medication patches with metallic backings have the potential to cause burns during MRI scans, according to a 2009 public health advice issued by the FDA. It is recommended that patients take off any medication patches before having an MRI and replace them with fresh ones when the scan is finished.(10)

Selection of percutaneous therapeutic agent

PERCUTANEOUS ABSORPTION

The movement of chemicals from the outer surface of the skin to blood stream.

- substance's entry into a certain layer is known as penetration.
- Permeation: the infiltration of one layer into another, which differs from the initial layer in terms of both structure and function.
- Absorption: system that facilitates a material enters the bloodstream.

Diffusion's first law is Fick's first law of diffusion helps to explain the passive-diffusion process of percutaneous absorption, which is how most medications are absorbed.

$$dQ/dt = JT = P.A.DC$$

JT = flux total transported through a unit area of skin per unit time in steady state ($\mu\text{g/hr}$)

A = area of the skin

P = the effective permeability coefficient

ΔC = drug concentration gradient through skin (12).

Epidermal Diffusion

Diffusion through the horny layer is influenced passively by physical variables. The percutaneous absorption to systematic circulation is a more complex process, consisting of two phases: epidermal diffusion and dermal clearance. Effective blood flow, interstitial fluid movements, lymphatic flow, and maybe other elements like interaction with skin components are necessary for percutaneous absorption. (13)





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FACTORS AFFECTING TRANSDERMAL DRUG DELIVERY

Physicochemical properties of penetrant molecule

Partition coefficient

Drugs that are soluble in water and fats are fastely absorbed to skin. Drugs with high lipophilicity and an intermediate partition coefficient ($\log K$ 1 to 3) can be administered using the intercellular route. For more hydrophilic compounds, the transcellular pathway most likely predominates. And unionized drug can be asily administered.

Molecular size

Molecular weigth 100- 500 dalton are taken.

Melting point / solubility

lipophilic molecules encorporates the skin quickly than more hydrophilic ones. When exposed to normal temperature and pressure, large melting point drug have comparatively limited water solubility.(14)

Physico-chemical Drug delivery parameters

Release characteristics

The drug's solubility in the vehicle indicates the release rate. The drug's intersurface partition coefficient in between the skin tissue and the delivery mechanism.

Composition of drug delivery:

The drug delivery system influences the stratum corneum's permeability through hydration, mixing with skin lipids, or other sorption-promoting actions with drug elution rate. Similar to salicylic acid, methyl salicylate exhibits more lipophilicity than its parent acid and produces a greater percutaneous absorption when administered to the skin from fatty carriers.

Transdermal permeation enhancement

Organic solvents -

Because partial leaching process of the epidermal liquids caused by these agents, the absorption of oil-soluble medicines is enhanced, improving the skin's conditions for wetting as well as for epidermal and follicular penetration. such as cyclohexane, acetone, ethyl ether, benzene, and chloroform. Dimethyl sulphoxide has been demonstrated to have a permeation-promoting effect on a range of medicines, including antibiotics, quaternary ammonium compounds, hormones, dyes, iodine, and local anesthetics.

Surface active agent

The action of surfactants is thought to be responsible for improving skin wetting, lowering surface tension, and facilitating penetration. For example, sodium dioctyl sulfo- and sodium lauryl sulphate(15)

TDDS Componentes

Polymer matrix

The polymers employed in TDDS should be chemically and biocompatible with both the drug and other system elements like PSAs and penetration enhancers. They should also be of safe status and distribute a medicine consistently and effectively for the duration of the product's stated shelf life.(16)

- a. **Natural polymer:** chitosan, natural rubber, cellulose derivatives, zein, gelatin, shellac, and waxes.
- b. **Synthetic elastomers** : Butylrubber, nitrile, acrylonitrile, neoprene, silicon rubber, polybutadiene, hydrin rubber, and polyisobutylene
- c. **Synthetic polymers** : ethylene, propylene, polyvinyl alcohol, polyvinyl chloride, polyacrylate, polyamide, polyurea, polyvinyl pyrrolidone, and polymethyl-methacrylate.(17)



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Drugs having a limited therapeutic window, high first pass metabolism, or short half lives . appropriate combination of physicochemical and biological qualities should not be ionic, have a low molecular weight (less than 500 Daltons), have a low melting point (less than 200°C), and be sufficiently soluble in oil and water (log P in the range of 1-3). day). selegiline for depression, Metadate disorder, rivastigmine for Parkinson's and Alzheimer's dementia, and rotigotine for Parkinson's disease have recently been licensed as TDDS.(24).

Permeation enhancers

Are pharmacological substances that raise stratum corneum permeability in order to reach higher therapeutic concentrations of the medication candidate. Proteins and lipids, which are structural elements of the stratum corneum, are interacting with penetration enhancers. They affect the stratum corneum's protein and lipid packing, which chemically modifies the barrier's activities and increases permeability. Dimethyl sulfoxide, ethanol, fatty acids and esters, pyrrolidones, etc. are a few permeation enhancers .(25)

Pressure sensitive adhesive (Self Adhesive)

A PSA is material supports the preservation of close contact between the skin's surface and the transdermal system. It should be aggressively and persistently sticky, adhere using just finger pressure exerted, and exert a strong holding power. It should also be able to be removed from the soft area.(26) polyacrylates, and polyisobutylene.. The selection process for drug-in-adhesive matrix systems will be based on how quickly the drug and penetration enhancer diffuse through the glue. PSA should ideally not change medication release and be compatible with biology and physicochemistry.(27)

Release liner

The patch is stored with a protective liner covering it .Before applying a patch to the skin, release liner must removed and disposed of since it comes into close contact with the transdermal system and should be both chemically and physically inert. such as polyethylene or polyvinyl chloride, and a release coating layer, consisting of silicon or Teflon, make up the release liner.

Backing laminate

Possessing a low speed of steam movement for increasing skin moisturizer and, thus, increased drug permeability on the skin .Compatibility is must with the transdermal system, as it will be used during application. Having a superior yield capacity and being non-irritating Polyethylene film, polyester film, polyolefin film, and aluminum vapor coated layer are a few types of laminate backings.

TYPE OF TRANSDERMAL PATCHES**Single layer drug-in-adhesive patches**

A reservoir for drug dispersion is made of a one membrane of sticky polymer. After the deposition into and adhering to the single polymer layer medication is released from the backing laminate layer that supports the drug reservoir . example is methylphenidate is the transdermal product Day-trana

Multilayer drug-in-adhesive patches

The two layers of multilayer transdermal patches are an adhesive layer with active ingredient layer and regulated drug release over time. This patches contains a fixed substrate laminate and a transient protective layer. Hormone therapy, medications that promote quitting smoking, and painkillers are all delivered via multilayer patches. (28)

Matrix system

The active ingredient storage modified for disperse the medication via single or two membrane percutaneous patch onto an adhesive polymer. This drug polymer matrix is deposited in sealing layer by solvent casting or melting the





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sticky polymeric components there are several commercial version of these transdermal patches available the climara transdermal patch for ex. Has 100 microgram of estradiol for a single application day.(29)

Transdermal vapor patches

Are made of one adhesive polymer layer along a steam expoler feature that allows vapor to be released. There are several vapor dermal patches on the market, each with a distinct purpose. Nicoderm CQ, for instance, are transdermal patches that release essential oils and include nicotine vapor that can aid in quitting smoking.

Example

1. Clonidine. Catapres-TTS High blood pressure
2. Selegiline Emsam Depression

Transdermal microreservoir patches

Combine a pharmacological reservoir with matrix dispersion. The drug is halted in water hydrophilic polymer solution to construct the reservoir. The drug suspension is then uniformly dispersed on a lipophilic polymer. High pressure is applied during dispersion, forming thousands of minute, unleachable spheres in the process. The drug level in the plasma is kept constant by the drug release profile, which adheres to a zero order rate of kinetic drug release .(30)

TRANSDERMAL PATCHES FORMULATION OF DIFFERENT ANTIHYPERTENSIVE DRUGS :

Atenolol

Atenolol, chemically known as 4-(2-hydroxyl-3-isopropyl aminopropoxy) phenylacetamide, is for treatment of hypertension , chest pain ,failure of heart , and myocardial infarction. It is a selective antagonist of the β_1 -receptor. Atenolol is a good option for TDDS administration because to its physicochemical characteristics, which include its low molecular weight (266.336), acceptable elimination half-life (6-7 hours), and modest water solubility. Based on assessment trials, the polymeric film comprising the medication, ethylene glycol, PVP, and Eudragit RL 100 was chosen for transdermal delivery(36). PEG-400 forsoftening agent in the mercury product process used to create the polymeric films. In the investigation, two distinct penetration enhancers—urea and dimethyl sulphoxide (DMSO)—were used. A variety of criteria were used to assess the dried polymeric film, such as thickness homogeneity, drug content, in vitro drug release from films, and in vitro drug skin penetration.Using a mercury substrate and a solvent evaporation process, the transdermal patch was created. Atenolol was added to a polymer solution that had been produced in ten millilitres of ethanol. During patch casting, the plasticizer and permeability enhancer were introduced. Glass rings set on a mercury surface were filled with the solution, and they were left to dry in the air for a whole day. From semi-dried patches, circular patches with a diameter of 2 cm (3.14 cm²) were cut and put in vacuum desiccators.(31)

Metoprolol

One API to recover mild to moderate essential hypertension is metoprolol tartrate. It functions by inhibiting beta1 adrenoreceptors and is nearly entirely absorbed (95%) upon oral administration; however, due to significant presystemic metabolism (40–60%), the systemic bioavailability varies greatly. After two to three hours, peak plasma concentrations are reached. Due to the medication's four-hour plasma half-life, regular dosage is required to keep the medicine at therapeutic blood levels throughout the duration of a patient's treatment. As a result, MT is a perfect choice for transdermal medication administration.(38) In a fabricated stainless steel apparatus, polymeric films were cast onto aluminum foil to prepare TDDSs. The device was made out of a 14 x 14 x 2 cm wooden block that could be screwed onto to hold a 9 x 9 x 1 cm stainless steel plate with a 4 cm diameter cylindrical cup. Before the device was screwed together to cast the films, a thick layer of aluminium foil was sandwiched between the steel plate and the wooden block. Mixing Methacrylic acid copolymer and polyvinyl alcohol in a mixture of DCM and IPA (80:20 v/v) along with 10% (w/w) of metoprolol tartrate, 5% (w/w) of plasticizer DBP, and 5% (w/w) of penetration enhancer (\pm) menthol (based on total polymer weight) were used to create the polymeric solution (10% w/v).The solvent was



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allowed to evaporate at room temperature (32°C and 45% relative humidity) for 24 hours after the solution added onto the aluminum foil that had been placed to base of the cylindrical cup of the apparatus mentioned above. Following drying, the films, along with the aluminium paper which covers that functioned as the backing film, were divided into patches measuring 6.74 cm² in area using a circular metallic die with an internal diameter of 2.93 cm. Next, the backing film was protected with a sticky tape with a flange left around the edge for simple adhering. Lastly, a release liner made of thin aluminum foil was applied to the opposite side; this could be quickly removed before the patch was applied to the skin. After that, the TDDSs were kept for seven days at room temperature in sealed containers before being used.

RESULT

The polymers displayed λ_{max} different from that of the medication, indicating that they did not interfere with the UV spectrophotometric technique utilized for the study. The maximum quantity of medicine released in 48 hours, $95.04 \pm 2.7\%$, came from the formulation M-4 that carried PVA and Eudragit RL-100 in an 8:2 ratio. The formulation M-4 containing Eudragit RL-100 and PVA in an 8:2 ratio had the largest cumulative quantity of medication released in 48 hours, at $95.04 \pm 2.7\%$. Formulation M-4 once again had more medication penetration rate, measuring 909. Following additional research, formulation M-4 was chosen as the optimal formulation and put to use. Based on the rise in drug release and permeation with an increase in Eudragit RL 100 quantity in formulations M-1 to M-4, the results indicate that Eudragit RL 100, a freely permeable polymer, has a significant impact on drug release and permeation.(32)

PROPRANOLOL

Arrhythmias of the heart, hypertension, and angina pectoris are all treated with propranolol hydrochloride. Given that it has a short terminal elimination half-life of three to five hours and that frequent dosage is required to maintain the therapeutic blood level for an prolonged time of treatment, it is the medication of choice for sustained release formulations. The medication has a limited bioavailability (15–23%) when taken orally because of hepatic first pass metabolism and its low molecular weight (295.81) further suggests that transdermal administration is the most appropriate method of administration. By employing a glass mold and the solvent evaporation process, propranolol percutaneous patch were created using three polymers in two distinct combinations and proportions, such as Ethylcellulose with Polyvinyl pyrrolidone and Ethylcellulose resin with HPMC K4M. The backing layer was created by adding 4% w/v PVA solution to distilled water, then drying in an oven at 60°C for six hours. Each polymeric combination's added in chloroform. As a plasticizer, dibutyl phthalate (30% w/w) of the polymer composition was applied. To achieve a homogenous dispersion, propranolol hydrochloride was added at a concentration of 21% w/w of biopolymer and agitated using a mechanical stirrer. Each mould's makes Polyvinyl Alcohol film was filled with a 2 ml dispersion. A funnel was placed above the mold to regulate the rate of evaporation. The mold was then dried in a thermal dryer at six hours at 40 °C, and the dry material was kept in desiccators for later use. Finally, the degree of propranolol spreads from the transdermal patches indicated that the films with a higher PVP F6 (6:1) proportion were appropriate for once-daily drug delivery, and the films with a higher EC proportion were appropriate for a prolonged regimen of sustained drug delivery through transdermal route for a duration of more than 48 hours.(33)

LABETOLOL

These days, the primary and most commonly prescribed medication for the long-term management of hypertension is labetalol (mol weight: 364.9). After being taken orally, labetalol is quickly absorbed from the digestive system; nevertheless, due to its substantial first pass metabolism, its oral bioavailability is still only 25%. The majority of biotransformation of this drug occurs in the liver, with the metabolites being eliminated in the urine along with very little levels of the original drug. The principal metabolites of labetalol do not have any appreciable effect – inhibiting consequences. Because of its short plasma half life (three to five hours) and inadequate bioavailability, long-term oral betametalol treatment for hypertension typically leads in unsatisfactory patient complaints. Eudragit E PO: Plasdone (Series A) & Eudragit RL 100: Plasdone S 630 (Series B) were used in varying ratios to make the transdermal patches



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having matrix containing Labetalol hydrochloride. To achieve a total weight of 800 mg, the polymers were raised in various ratios and dissolved in ethanol. To create a homogeneous solution, labetalol hydrochloride was gradually added to the polymer solution and carefully mixed. A 5% w/w addition of basil oil was applied as a penetration enhancer, and 20% di-n-butyl-phthalate was utilized as a plasticizer. The drug polymeric solution was applied to the mercury surface, which had an internal diameter of 6 cm. The surface was then dried at 24 hr. at $32 \pm 2^\circ\text{C}$ and $45 \pm 5\%$ relative humidity. The films were sliced into a 6.74 cm² patch after a day, and a backing membrane made of laminated aluminum foil was adhered to. Transdermal films were stored in a desiccator until further used.

RESULT

Greater release and greater permeation were seen in patches containing Plasdene S 630 and EPO compared to patches containing Plasdene S 630 and Eudragit RL 100 together. Preliminary investigations also showed that the medication was evenly dispersed across the film and that it did not interact with the carriers that were utilized to create matrices. Whereas patches with increasing Concentrations of Eudragit EPO demonstrated an anomalous transport, patches containing higher Concentrations of Plasdene S 630 demonstrated a release mechanism toward Fickian first order diffusion release mechanism. (34)

CARVEDILOL

The most often recommended medication for the long-term management of hypertension is carvedilol. Carvedilol is quickly absorbed through GI area (81%) after oral administration; however, due to considerable first-pass hepatic metabolism by cytochrome P450, the oral bioavailability is still low (e.g., 23%). The half-life of carvedilol is six hours. Create distinct matrix patches using varying ratios of lipophobic and lipophilic polymer combinations, such as (a) polyvinylpyrrolidone (PVP) and ethyl cellulose (EC), and (b) carvedilol- containing ERL 100 and ERS 100; In order to manufacture transdermal patches of matrix containing carvedilol, several ratios of ethyl cellulose: polyvinylpyrrolidone were used. The biopolymers mixed in chloroform after being raised in weight to 400 mg in various ratios. To create a homogeneous solution, carvedilol (2.5% wt/wt) was gradually added to the polymer solution and well mixed. As a plasticizer, di-n-butyl-phthalate was used. The drug polymeric solution was applied to the 25 cm² mercury surface and allowed to air dry at ambient temperature in a dust-free atmosphere. The films were sliced into a 5 cm² piece and covered with a polypropylene film backing membrane after 24 hours. Before being used again, the percutaneous patch put in drying chamber. (35).

CONCLUSION

The percutaneous absorption device is used for topically administer medications by skin at a previously selected place for systemic effects. Antihypertensive medication delivered transdermally can offer the ideal dosage to treat the illness with the fewest possible negative effects. This analysis of many high blood pressure medications revealed that using this delivery method enhances both patient compliance and bioavailability. This may also result in the long-term management of hypertension being treated with healthcare at a cost that is economical. The primary constraint is that the medication must have particular physical and chemical characteristics that allow it to pass through the skin; as a result, not all antihypertensive medications may be administered in this way. The market for transdermal medication delivery is expanding, and during the coming years, there is a chance that this industry may develop even more.

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Table 1. Examples of Transdermal Patches and Examples.

Transdermal Patches	Uses
Nicotine(vapour patch)	Quitting tobacco use
Fentanyl	Analgesic (extreme pain)
Nitroglycerine	Angina Pectoris
Lidocain(Lidoderm)	Peripheral pain
Buprenorphin(BurTrans)	Sever chronic pain
Flector(diclofenac epolamine)	Alleviate acute pain, fibromyalgia,arthritis
Scopolamine by U.S FDA in 1979	Pain and inflammation

Table 2 :Ideal properties of Drug for TDDS

Parameters	Ideal Properties
Dose	Should low(<20mg/ day)
Molecular Weight	<100
Partition Coefficient	Log P (octanol water) between 1.0 and 4.0
Therapeutic index	low
Skin reaction	Non irritating and non sensitizing
Oral bioavailability	Low
Half life	10 hour or less

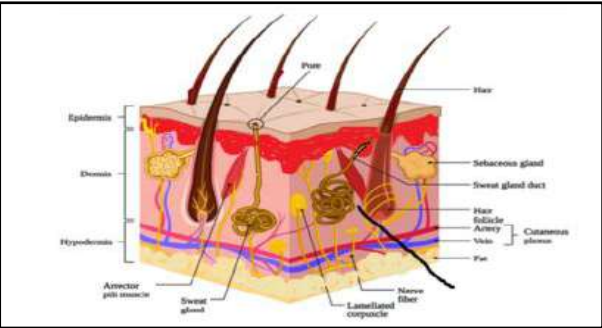
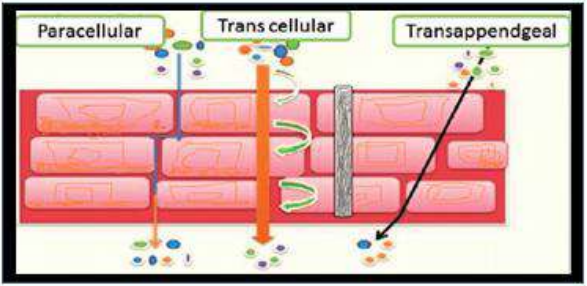
Table 3. Examples of synthetic Polymers

Cross Linked Polymers	Uses
Polyethylen glycol	Matrix former for TDDS(18)
Eudragits	Matrix former for TDDS(19)
Ethyl cellulose and polyvinylpyrrolidone	Matrix former for TDDS(20)
Hydroxypropylmethyl cellulose	Matrix former for TDDS(21)
EVA	Rate controlling membrane(22)
Silicon rubber and polyurethane	Rate controlling membrane(23)





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<p>Fig 1. Structure of Human skin</p>	<p>Fig 2. Permeasion Through Skin</p>





Preliminary Phytochemical Exploration and FTIR Characterization of the Moss *Himantocladium plumula* (Nees) M. Fleisch

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ABSTRACT

Phytochemical studies on *Himantocladium plumula* (Nees) M. Fleisch., a moss of the Neckeraceae family were conducted with respect to qualitative analysis in addition to FTIR spectroscopic studies to identify functional groups and compounds. Plant samples were collected from Kallar adjoining the Ponmudi peak, dried, powdered and solvent extracts were prepared using Soxhlet apparatus in petroleum ether, hexane, chloroform, ethyl acetate, acetone, methanol and water. Qualitative analysis showed the presence of an array of phytochemicals. FTIR analysis indicated the occurrence of complex compounds with different chemical bonding activity and the occurrence of organic compounds as well as inorganic ions. The nature of substances identified strongly indicates the functionalities of this species concerning stress resistance and bioactive potentiality.

Keywords: *Himantocladium plumula*, Neckeraceae, qualitative analysis, FTIR spectroscopy, phytochemicals

INTRODUCTION

The world of plants involves several unique groups of which bryophytes stand out with regard to their amphibious nature and predominantly gametophytic terrestrial habits. This collection of distinct plant life comprises members that colonise and inhabit substrata bearing harsh and extreme conditions which is not supportive of any other life



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forms except perhaps the Lichens. Ecologically they are found to be an important link in the process of succession modifying rocky substrata enabling rock weathering creating soil surfaces conducive to sustaining higher plant forms. Preferring moist shady climes, they are found to have species exhibiting desiccation resistance indicating the existence of diverse members. For a long time, the phytochemistry of bryophytes has been neglected due to their small size and the challenges associated with collecting large, pure samples. Identifying them, even under a microscope, is exceedingly difficult. Moreover, they have been deemed nutritionally useless to humans[1]. In recent years the focus of research in bryophytes has shifted to aspects that have not been explored till now including molecular, pharmacognosic, ethnobotanical and phytochemical realms. Traditionally the attention of investigators hinged on higher plant forms and the few who ventured into bryophyte research focused on taxonomic studies resulting in several unexplored areas that requires intensive study. The available literature indicates that several species of commonly occurring bryophytes of the forests of Kerala have not been investigated and the existing research indicates the potential of this group with regard to secondary metabolites and bioactive potential[2]. This work focusses on the qualitative characterisation as well as FTIR analysis of the moss *Himantocladium plumula* (Nees) M. Fleisch. A search on the available literature on the phytochemistry of *H. plumula* reveals the absence of studies in this regard and based on literature available on bryophytes in general the possibility of identifying molecules with bioactive potential that can be applied in a variety of therapeutic domains. *Himantocladium plumula* is a member of the Neckeraceae family in the main category of the simple or leafy mosses (Bryopsida)[3]. This moss is found growing predominantly on rocks lining flowing streams and rivers under the shade of riparian canopies of arboreal foliage and are seen to extend into the bark of trees and onto lianas as well as woody creepers and climbers growing on or adjacent to such rocks. This species is found to adjust more favourably to conditions of desiccation stress when compared to other bryophyte species, this and other characteristics can be understood more precisely with investigations into the molecular and chemical nature of the plant. An effort is made in this work to identify the presence of secondary metabolites as well as to identify the functional groups through FTIR analysis which can be used to identify molecules of importance.

MATERIALS AND METHODS

The work involved initial characterisation of secondary metabolites through qualitative analysis and this was followed by determination of the molecular nature through FTIR techniques.

Collection and Preparation of the Plant Sample

Samples of the bryophyte under study were gathered from the Kallar region, nestled at the base of the Ponmudi peak in the Thiruvananthapuram district of Kerala State, India. *Himantocladium plumula* (Nees) M. Fleisch. exhibits synoicous reproduction, with elongated stems reaching 5 cm to 7 cm and arranged in a frondose manner, featuring octastichous leaf arrangement, particularly at the base. The leaves are characterized by rugose or somewhat complanate texture with regular shallow lunate undulations[4]. Branching displays a heterotrichous pattern reminiscent of asexual propagation through prostrate runner formation. Among Neckeraceae species, *H. plumula* stands out due to its synoicous nature. The specimens were delicately removed from their natural habitat and carefully placed in paper bags, ensuring the entirety of the plant body was collected. After obtaining a sufficient quantity, the material underwent a thorough washing in running water to eliminate all traces of soil and debris. Subsequently, the material was shade-dried for 15 days in preparation for extraction, followed by pulverization using a mortar and pestle.

Soxhlet extraction

Extraction was done using a Soxhlet apparatus, 50 grams of the powdered plant material was loaded into the apparatus and it was subject to boiling using solvents selected based on the polarity index. The sequence of solvents used from non-polar to polar were Petroleum ether, hexane, chloroform, ethyl acetate, acetone, methanol and water.



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The solvent extracts were collected in 30 ml glass vials and water extracts were stored in refrigerators at 3°C to prevent decomposition and for further studies.

Qualitative Analysis

Each of the solvent extracts was subjected to qualitative tests for various organic molecules, conducted using standard protocols [5-7]. Phenol is assessed using the Lead Acetate Test, while Tannin presence is determined through the Ferric Chloride Test. Flavonoids are detected using the Ferric Chloride Test, Saponins are identified via the Foam Test. Terpenoids are examined using the Liebermann-Burchard Test, Alkaloids with Wagner's Reagent. Glycosides are evaluated using the Kellar-Killani Test, Steroids are detected through the Liebermann-Burchard Test, Quinones presence is determined by the HCL Method, the test for Coumarin involves treating the substance with alcoholic KOH or NaOH, with the presence of a dark yellow color indicating its presence [8].

FTIR Analysis

Dried and powdered plant samples were used for FTIR (Fourier Transform Infrared Spectroscopy) with 2 grams of plant material used. FTIR spectroscopy can be performed on minute quantities of plant material and is a vibrational spectroscopic technique providing data on absorbance by atoms when exposed to medium infrared radiation. The data is expressed as wave number (cm^{-1}) and not wave length providing a direct indicator of the energy level of atoms. This data can be used to identify the nature of chemical bonds with which the atoms are involved and the functional groups in which they are involved leading to molecular Identification (9). Result of FTIR analysis was obtained as graphical data and compared to data bases to identify the functional groups present.

RESULTS AND DISCUSSION

Qualitative Analysis

The various phytochemical components were extracted in a series of non polar to polar solvents by hot continuous Soxhlet extraction. Characterisation of the extracts by qualitative methods could detect the presence of secondary metabolites in *Himantocladium plumula* shown in the table 1. The *H. plumula* extract is rich in alkaloids, terpenoids, and glycosides across all solvent extracts, with additional presence of saponins in the water extract and steroids in the hexane extract. Tannins were not detected in any of the extracts. Petroleum Ether extract didn't show the presence of any of the tested secondary metabolites. Hexane extract showed the presence of alkaloids, steroids, and glycosides. In Chloroform extract alkaloids, terpenoids, and glycosides were detected. Ethyl acetate extract exhibited the presence of terpenoids, alkaloids, and glycosides. Similar to the ethyl acetate extract, acetone extract: contained terpenoids, alkaloids, and glycosides. In methanol extract alkaloids, terpenoids, and glycosides were present. Water extract showed the presence of saponins, alkaloids, and glycosides. Saponins, present in methanol and water extracts, indicate the presence of triterpenoid and steroid saponins[10]. Tannins are known to be extracted in solvents with high polarity indices, such as methanol and water. Additionally, studies have shown that hot water is particularly effective for tannin extraction[11]. Terpenoids, found in polar solvents like ethyl acetate, acetone, methanol and water, suggest the presence of volatile terpenoids with significant bioactive potential. These volatile terpenoids also contribute to the desiccation-resistant properties of Bryophytes [12]. Alkaloids are extracted in various solvents based on their polarity, with different alkaloids showing solubility in different solvents. Steroids are primarily detected in solvents with lower polarity indices such as petroleum ether, hexane, and chloroform, indicating the presence of non-polar steroids such as brassinosteroids, bufadienolides, cardenolides, and vertebrate-type steroids [13]. Glycosides are detected in both polar and non-polar solvents, suggesting the presence of various groups of glycosides with potential bioactive functions, consistent with their abundant presence in many plants.

FTIR Analysis

FTIR spectroscopy, or Fourier Transform Infrared Spectroscopy, is an analytical technique utilized to identify and analyze the chemical composition of substances. It operates by measuring the interaction between the sample and



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infrared radiation. When exposed to infrared radiation, molecules within the sample undergo characteristic vibrations corresponding to their chemical bonds. By examining the absorption of infrared light across various wavelengths, FTIR spectroscopy yields comprehensive insights into the functional groups, molecular structure, and composition of diverse materials. These materials encompass organic and inorganic compounds, polymers, proteins, and pharmaceuticals. The FT-IR characteristic absorption bands and their assignments reveals the Finger print band features of *Himantocladium plumula* (Figure1, Table2). The presence of 11 absorption bands here denotes the presence of complex molecules. The absorption bands 3275.37 cm^{-1} and 2918.75 cm^{-1} indicate single bond regions and 3275.37 cm^{-1} is an indicator of hydrogen bonding confirming the presence of hydrate, hydroxyl, ammonium or amino. The band 2918.75 cm^{-1} indicates long chain linear aliphatic compounds. The band 1629.35 cm^{-1} informs double bonds or aromatic compounds with C-H bending vibration indicated by the band 829.55 cm^{-1} [14].The functional groups identified and assignments are provided in the table 2 below,

CONCLUSION

Himantocladium plumula (Nees) M. Fleisch. is a moss of the Neck eraceae family with no data or studies reflecting its phtochemistry including any literature on the metabolite types or specific compound identification. The qualitative and FTIR analysis studies have revealed a wealth of data providing insights into the presence of substances with potential bioactive functions which can be revealed through further investigations. Qualitative studies have provided information on the presence of saponins, tannins, terpenoids, alkaloids, steroids and glycosides. The occurrence of saponins and terpenoids in polar extracts indicates the presence of triterpenoid saponins, steroid saponins and volatile terpenoids. The FTIR spectroscopy data indicates the presence of complex compounds involving both organic substances and inorganic ions. The data from this study indicates the presence of distinctive physiological characteristics related to stress like especially desiccation resistance and bioactive potentiality providing scope for further investigation.

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Table 1: Preliminary Qualitative Analysis of Phytochemicals in *Himantocladium plumula*

Tests	Results						
	Extracts						
	Pet. Ether	Hexane	Chloroform	Ethyl acetate	Acetone	Methanol	Water
Saponins	-	-	-	-	-	+	+
Tannins	-	-	-	-	-	-	+
Phenols	-	-	-	-	-	-	-
Terpenoids	-	-	-	+	+	+	+
Alkaloids	+	+	+	+	+	+	+
Flavanoids	-	-	-	-	-	-	-
Steroids	+	+	+	-	-	-	-
Glycosides	-	-	+	+	+	+	+
A.Quinones	-	-	-	-	-	-	-
Coumarins	-	-	-	-	-	-	-

Table 2: FT-IR spectral analysis showing the peaks and respective functional groups of *Himantocladium plumula*

Wave number (cm ⁻¹)	Type of molecule	Functional group/assignment
3275.37	Common inorganic ions	Ammonium ion
2918.75	Methyne(>CH-)	MethyneC-H stretch
1629.35	Olefinic (alkene)	AlkenylC=C stretch
1369.84	Methyl(-CH ₃)	gem-Dimethylor“iso”-doublet
1257.62	Ether and oxy compound	Aromatic ethers,aryl-Ostretch
1201.27	Tertiary amino	Tertiary amine, CN stretch
1160.27	Secondary amino	Secondary amine,CN stretch
1023.62	Phosphorus-oxy compounds	Aliphatic phosphates (P-O-C stretch)
829.55	Common inorganic ions	Nitrateion





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461.91	Thiols andthio-substituted compounds	Aryl disulfides (S-Sstretch)
422.12	Iron compounds	Fe-O vibration

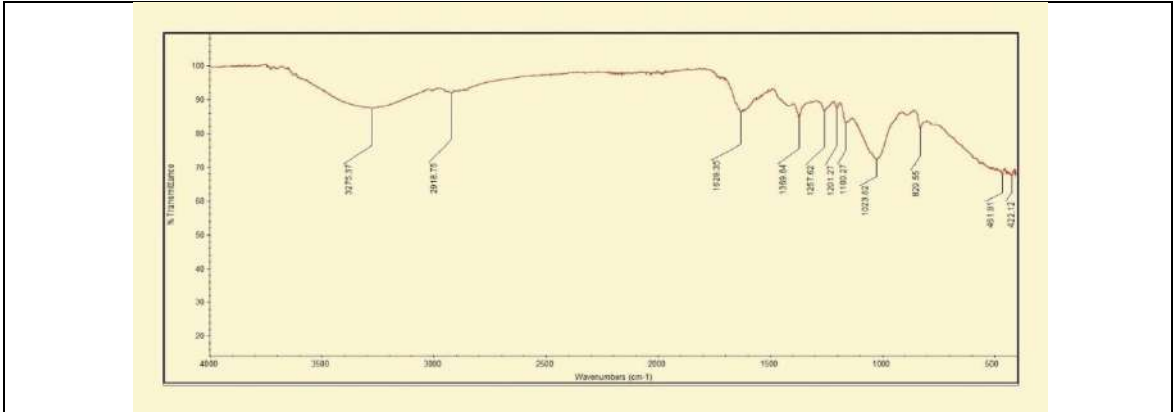


Figure 1: FT-IR finger printing chromatogram of *Himantocladium plumula*





RESEARCH ARTICLE

A Strategic Approach to QMS Compliance: Insights Gleaned from FDA Warning Letters

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ABSTRACT

The Quality Management System (QMS) is essential for achieving effective regulatory compliance in the pharmaceutical industry, particularly in light of increasing scrutiny from the FDA. QMS provides a structured framework that ensures adherence to regulatory requirements by establishing standardized procedures and processes. It addresses critical issues such as quality failures and insufficient corrective actions, thus mitigating risks associated with regulatory inspections. By promoting a culture of continuous improvement, QMS enhances overall product quality and fosters customer satisfaction. It facilitates compliance with dynamic regulatory environments, ensuring that organizations remain prepared for inspections and audits. Furthermore, QMS optimizes operational efficiency by streamlining processes, reducing costs, and enhancing yield. This article examines the integral role of QMS in maintaining regulatory compliance and outlines its key modules for effective implementation. Ultimately, a robust QMS not only minimizes the likelihood of receiving 483s and warning letters but also contributes to the long-term success of pharmaceutical organizations.

Keywords: Inspectional FDA 483's, warning letters, CAPA, QMS





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INTRODUCTION

Pharmaceutical enrollment dossiers are crucial documents that applicants submit to regulatory bodies for evaluation before releasing their goods for sale [1]. It contains the information acquired from every study in an exact format called the Common Technical Document (CTD) format, which is kept up to date by the ICH [2]. Both novel and generic medications have significantly increased worldwide as a result of the pharmaceutical industry's globalization. Quality, safety, competitiveness, and the future of the pharmaceutical sector and Drug creation are all significantly impacted by these global shifts [3]. Experts have also been actively involved in the global effort to prevent the proliferation of subpar medications and the spread of counterfeit medications [4]. Pharmaceutical Producers are currently concentrating on efficient dossier management given the regulatory result determines how these marketing approvals turned out [1,5]. Effective planning, formatting, and compilation are necessary to gain market acceptance beforehand, which may ultimately result in increased earnings and prices. The number of The Office of Generic Drugs (OGD) is reviewing registration applications has significantly increased concurrently [6,7]. Several tactics have been developed by the Food and Drug Administration (FDA), the US pharmaceutical regulator, to expedite the review of Marketing Authorization Applications (MAA). QbR-QOS, or question-based review-quality overall summary, was one such tactic [8]. For the Chemistry Manufacturing and Controls (CMC) evaluation of an application, the QbR has two functions [8]. Initially, it offers a guide to the reviewer in determining the degree of risk involved in the product's design and manufacture as well as whether the product is of high quality [9,10]. Second, it makes the reasoning that reviewers use in their CMC reviews transparent to sponsors. When it comes to finding the flaws that are directly related to important problems with product quality, QbR is crucial because fixing these problems results in a better product when it is approved [8,11]. The focus of this article will be on how to stop FDA 483s, warning letters, import alerts, scientific misconduct, and regulatory noncompliance.

QMS combining ISO and GMP

As previously said in a few recent guidelines, authorities generally have a clear preference for Quality Management Systems (QMS) e.g. in ICH Q7a, Section 2.11 "Each manufacturer should establish, document, and implement an effective system for managing quality that involves the active participation of management and appropriate manufacturing personnel" In conclusion, ISO 9002 already mentioned in the introduction: It is stressed that the technical (product) stated requirements and the quality system requirements outlined in this International Standard are complimentary, not interchangeable. The API makers have access to a 1997 CEFIC/APIIC guidance on the integration of the GMP requirements with the QMS criteria [13].

Present Pharma Framework

FDA 483s, warning letters, Notice of Violations, and import alerts have resulted from a spike in regulatory non-compliance (Violations) at a number of drug plants during the 2013–2014 period [14]. Despite the fact that laws, regulations, and guidance have been in place for a long time in the pharmaceutical industry, the numerous FDA 483s, warning letters, and import alerts demonstrate that businesses are facing non-compliances and implementation issues. In order to guarantee that the public has access to safe and effective medications as soon as possible, authorities are actively involved in the pharmaceutical industry and have implemented stringent regulations. Nevertheless, they have observed a number of businesses disregard these rules, which has resulted in the denial of product approval or the closure of a facility [15]. USFDA inspectors found that drug ingredients that had failed quality testing were retested, circumventing regulatory processes and deliberate manipulations, perhaps in an effort to reverse the positive results. The experts advise businesses to put quality and regulatory compliance first because these are core values shared by all governments across the globe.

Regulatory non-compliance in the modern era

The USFDA has discovered the retesting of medication ingredients that had failed quality testing, as well as procedural errors, a lack of educated staff, and a failure to monitor and document quality-related activities, all in an



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apparent attempt to produce positive results [16,17] The fact that businesses submit inadequate FDA 483 responses to inspectional observations, which only provide one side of the story and omit crucial data, is another problem. This occurs when regulators identify noteworthy findings during inspections. Instead of identifying the issue, businesses turn to temporary solutions. Ultimately, the regulatory authorities may issue warning letters, refuse to approve a product, or shut down the plant [14].

FDA-Reported common violations

FDA has taken action against a number of companies for regulatory non compliances, including notices of violations (Table 2), import alerts, and 483 notifications. The outcome of an FDA inspection can vary from no necessary actions to the facility being shut down entirely and the company facing administrative, civil, or criminal charges. The U.S. pharmaceutical regulator even stated that it could refuse to approve any new applications or supplements until the required corrective actions are taken and approved in accordance with the rules.

The FDA's Present Approach to Successful Regulatory Compliance

The FDA's strategy for regulatory compliance prioritizes high-risk products, focusing on prevention and early intervention. It uses advanced technology, including data analytics and real-world evidence, to improve monitoring and decision-making. Through global collaboration with regulatory bodies and industry, the FDA enhances standards and inspection capabilities. A hybrid model of on-site and remote inspections is used to ensure flexibility, while robust quality practices and continuous improvement are emphasized. Transparent communication, education, and guidance support public and industry understanding, and enforcement actions like warnings and recalls ensure compliance. Finally, the FDA supports innovation with fast-tracking and flexible regulatory frameworks for essential treatments.

- Unannounced, unexpected inspections;
- Additional inspectors; new inspectors;
- Tough regulatory measures for non- compliances
- Enforcing businesses to conduct ongoing evaluations of their Quality Management System (QMS) in order to minimize quality issues, process nonconformances (PNC), material nonconformances (MNC), rectify cGMP violations, and implement Corrective Action Procedures (CAPA) when mistakes are made.

Regulatory Non- Compliance in India

Nearly 80% of the active pharmaceutical ingredients (API) needed by the US are imported, as are about 40% of the finished drugs. India continues to be a location of great importance to the US health regulator because it has the most FDA-approved drug manufacturing facilities (more than 150 formulation facilities) and is the second-largest pharmaceutical supplier to the US market in terms of volume of generic drugs. Indian pharmaceutical companies hold 13 percent of the generic market in the United States. The Centre for Monitoring of the Indian Economy (CMIE) estimates that between 2008 and 2013, India's exports of generic drugs to the US market grew by 27% a year. Indian companies are especially vulnerable to the heightened regulatory scrutiny because of their greater market share. Additionally, the FDA takes action against the biggest pharmaceutical companies for violating various US regulations, which can result in import alerts, unannounced inspections and other repercussions.

India's USFDA Checks

A Quality Management System (QMS) includes policies, standards, and procedures that guide a company in meeting legal and operational requirements. Experts recommend that QMS should emphasize sustainability, as this focus promotes systematic thinking, transparency, and accountability. This approach is expected to help reduce quality issues over time [19]. QMS[20]is essential for regulatory compliance in drug production, coordinating activities to direct and control continuous improvement in effectiveness and efficiency [21] QMS begins by identifying customer prerequisites as key contributions as well as involves monitoring customer satisfaction to ensure these needs are met effectively [22]. Early QMS focused on product outcomes, but later shifted to teamwork and early problem detection through continuous improvement. Customer satisfaction now evolves with technology, market complexity, and competition, requiring QMS to be in a state of continual improvement. An effective QMS boosts business



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performance, helping organizations achieve their purposes and aims [20]. Software for automated QMS provides a systematic approach for reporting, evaluating, and managing quality issues, including discrepancies and non-conformances. It helps manufacturers ensure effective monitoring and decision-making for quality control [23]. Effective internal audits and continuous improvement are essential for regulatory compliance, especially in a competitive, tech-driven market. Automating QMS enhances product quality, efficiency, and customer value by streamlining processes and ensuring safe, effective drug production [24]

METHODOLOGY

This research adopts a qualitative approach to explore the role of Quality Management Systems (QMS) in regulatory compliance, focusing on data from FDA inspections, recalls, warning letters, injunctions, and seizures. A literature review will establish theoretical frameworks by analyzing peer-reviewed articles, industry standards, and regulatory guidelines, identifying gaps in current research. Data collection will involve retrieving quantitative metrics such as inspection frequency, recalls, and enforcement actions from the FDA's dashboard, alongside qualitative insights from warning letters and injunctions to understand regulatory challenges. A purposive sampling technique will select cases demonstrating significant QMS-regulatory interactions. Statistical methods will quantify the relationship between QMS implementation and compliance outcomes, while thematic analysis of qualitative data will uncover contextual patterns. Case studies of organizations with effective QMS implementations will provide real-world examples of best practices and challenges. Triangulation will enhance reliability and validity by cross-verifying data from FDA databases, literature, and interviews. Ethical considerations include informed consent, data confidentiality, and adherence to institutional guidelines to ensure research integrity. This comprehensive methodology aims to provide a systematic and credible analysis of QMS in achieving regulatory compliance.

RESULTS

From 2019 to 2024, the issuance of warning letters, injunctions, seizures, and product recalls highlights significant fluctuations in regulatory activities across industries. Warning letters peaked at 15,103 in 2019 but dropped dramatically to 2,504 by 2021 before surging to 17,351 in 2022 and stabilizing around 13,307 in 2024. This variability indicates changing enforcement priorities or external factors influencing regulatory actions. Similarly, injunctions peaked at 8 in 2019 and 2020 but declined steadily to 4 by 2024. Seizures showed a sharp drop from 2 in 2019 and 2021 to zero from 2020 onward, reflecting a shift in enforcement strategies or the effectiveness of compliance efforts. Product recalls also exhibited notable trends, with initial declines from 7,894 in 2019 to 5,309 in 2021, followed by a resurgence to 6,524 in 2024. These changes suggest an evolving regulatory landscape, influenced by shifting priorities, industry compliance, and safety measures. Sector-wise, medical devices accounted for the highest number of recalls at 15,718, driven by rapid technological advancements and stringent regulations. Food and cosmetics followed with 9,405 recalls, primarily due to contamination and labelling issues. Pharmaceuticals saw 7,339 recalls, highlighting the critical need for strict quality controls, while biologics, with 3,678 recalls, reflected their inherent complexity and risks. Veterinary products experienced 1,331 recalls, underlining their importance in animal health, whereas tobacco products had only two, possibly indicating effective oversight or lower inherent risks. These figures underscore the vital role of regulatory oversight in ensuring consumer safety across diverse sectors, reflecting both challenges and achievements in maintaining public health and trust.

DISCUSSION**Case Studies on Quality Failures**

Product: Drugs

Company Name: Med Office Saglik Endustri Anonim Sirketi

October 23, 2024



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Warning Letter 320-25-07 According to 21 CFR 211.100(a), your company did not create sufficient written production and process control procedures that would have ensured that the pharmaceutical products you produce had the identity, strength, quality, and purity that they claimed or were represented to have. Additionally, your company's quality control unit did not examine and approve those procedures, including any modifications. This letter describes problems with your equipment qualification, cleaning protocols, and manufacturing process validation. The FDA has found issues with your systems' sufficiency. Provide a thorough plan that addresses these issues: 1) design, validate, and monitor processes with vigilance over variation; 2) a timeline for finishing PPQ for each marketed drug; 3) process performance protocol(s) and equipment qualification procedures; and 4) your validation program to ensure state of control throughout the lifecycle, including PPQ and monitoring intra-batch and inter-batch variation. Additionally, improve your cleaning validation program by addressing worst-case scenarios for drugs with higher toxicities, potencies, lower solubility, and hard-to-clean characteristics. Assign swabbing locations, hold times, and areas that are challenging to clean. Describe the procedures in your change management system for new products or equipment as well. Summarize the most recent SOPs for equipment, processes, and product cleaning validation.

CONCLUSION

The issues at your facility are not limited to the violations listed in this letter. To stop recurrence, you must look into and fix any infractions right away. Regulatory action, such as seizure, injunction, or rejection of new drug applications, may follow noncompliance. On October 4, 2024, the FDA put your company on Import Alert 66-40 and threatened to deny admission of articles that were tampered with. Within 15 working days, kindly reply in writing outlining the necessary remedial measures and completion dates.

Product: Drugs

Company Name: MMC Healthcare Ltd.

Warning Letter 320-24-62

September 24, 2024

According to 21 CFR 211.22(a), your company did not set up a sufficient quality control unit wherein all components, drug product containers, closures, in-process materials, packaging materials, labelling, and drug products could be approved or rejected. Investigators discovered backdated signatures, additional data, and pages that were modified in your process validation reports during the inspection, and managers acknowledged their involvement. Your explanation of inadvertent backdating is insufficient since it does not include a thorough analysis of the problem or comprehensive corrective actions (CAPAs) for documentation procedures. Data integrity is essential to every CGMP procedure. To make sure your Quality Unit (QU) has the right power, resources, and supervision to maintain product quality, you must present a remediation plan. Along with an impartial evaluation of your documentation procedures and a thorough CAPA plan to guarantee proper record-keeping, this also entails assessing batch records, investigations, and QU duties.

CONCLUSION

The FDA has put your company on Import Alert 66-40 and may not approve new applications until all problems have been resolved. Under the FD&C Act, your items may continue to be denied entry into the United States if infractions are not corrected. You have fifteen working days to reply in writing, outlining the corrective measures you took to avoid a recurrence. Provide justifications and a completion timeline if corrective activities cannot be finished in this time frame. This letter is an opportunity to show compliance and address the shortcomings. [28]

Product Type: Drugs

Company Name: Diamond Chemical Co., Inc.

September 6, 2024

A sufficient documented testing procedure to evaluate the stability characteristics of drug products was not established or followed by your company (21 CFR 211.166 (a)).



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For hand sanitizer goods, your company failed to set up a sufficient continuous stability testing program to guarantee that the products meet quality, purity, strength, and identification requirements for the course of their shelf life. Your response, which cites continuous testing during the pandemic and the absence of evaporation in bottles filled with ethanol, is inadequate because it omits testing evidence showing that the products' chemical and microbiological characteristics stay within specification. Your pledge to stop producing FDA-regulated goods is respected, but you must give the FDA advance notice if you plan to start producing drugs again. Because of the infractions found, you should hire a trained consultant to assess your operations, help you comply with CGMP regulations, and do a thorough system audit. Correcting errors and making sure CGMP is followed are still the responsibilities of your top management.

CONCLUSION

To stop recurrence, you are in charge of looking into and dealing with any infractions at your establishment. If remedial measures are not implemented promptly, there may be legal or regulatory repercussions, including seizure and injunction. Your ability to receive export certificates or federal contracts may also be impacted by unresolved breaches. Until infractions are completely resolved, the FDA may refuse to approve further applications. Within 15 working days, kindly reply in writing with plans and corrective steps. Give justifications and a completion timetable if you are unable to finish them by this deadline. [29]

Impact of QMS

All issues, including deviations, non-conformances, and complaints, should be managed by a change control system that tracks changes throughout the product lifecycle, providing detailed information on the history, rationale, and differences between current and proposed changes. A deviation report initiates an investigation, where cross-functional teams from departments like QC, Production, Process Engineering, and QA work under the oversight of the QA department head to identify the root cause. The CAPA owner then categorizes corrective actions into audits, documentation changes, or training, and preventive measures are implemented to avoid recurrence. Once the effectiveness of the corrective actions is confirmed, the CAPA is closed if deemed satisfactory. The CAPA system is reviewed regularly during the monthly Quality Review Meeting (QRM) to assess its effectiveness and discuss key quality indicators for continuous improvement [22,32,33].

CONCLUSION

In conclusion, a robust Quality Management System (QMS) is essential for regulatory compliance in the pharmaceutical industry. QMS provides a structured framework for companies to ensure product quality, adherence to regulatory standards, and mitigation of risks related to non-compliance. Implementing QMS effectively can reduce the likelihood of receiving FDA warnings and import alerts, supporting both operational efficiency and long-term organizational success. The study highlights that continuous improvement, strong leadership, and a culture focused on compliance are critical to achieving sustainable success.

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Table 1. List of popular medications with FDA warnings and associated guidelines ¹

S.NO	Incident	Product	Manufacture/ Country	Impact (Loss of life/Hospitalization)	Regulation
1	Drug addiction	Alprazolam (or) Xanax	Upjohn/Pfizer	Highly addictive drug. A total of 211 deaths recorded	On a broader note, the FDA may wish to investigate why the medicine does not have the high-profile "black box" warnings associated with major health hazards when it comes to drug addiction and dependency. Xanax side effects include the potential to exacerbate subsequent panic attacks, which the patient may be striving to overcome.
2	Sedative effect	Morphine (or) MS Contin, Kadian	Purdue Pharma	Main active compound in opiates. A total of 191 deaths recorded	regulation pertaining to safety label revision.
3	Drug abuse	Diazepam (or) Valium	Roche	Habit forming and increase the effects of alcohol. 174 deaths recorded	legislation governing safety label revision.
4	Euphoric effect	Clonazepam (or) Klonopin, Cebercion	Roche	A total of 119 fatalities were noted.	regulation pertaining to safety label revision.





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5	Effect on nervous system	Oxycodone(or) OxyContin, Percodan	Purdue Pharma	Changes the way brain responds to pain. Euphoric effect. Atotalof237 death recorded	The FDA has approved new labelling that states that the product has physical and chemical properties that are expected to make injection abuse difficult and to decrease abuse via the intranasal route, after concluding that the reformulated form of OxyContin has abuse-deterrent qualities.
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Based in usfda warning letters in USA during over 2021 to 2024

Table.2 The FDA cited common infractions [18]

S.NO	Specifications	Observed Violations
1	Standards of hygiene	a) Inability to create suitable written protocols intended to avoid microbial contamination, errors, and variations b) Failed to keep the structures hygienic and clean. inadequate restroom and washing facilities were provided
2	Knowledge of procedures	a) Inability to guarantee that every individual involved in the production or handling of a pharmaceutical product possesses the required education, training, and expertise. b) Not always adhering to the authorized SOP
3	The discipline of data documentation	a) The laboratory records lacked the comprehensive data obtained from all the tests required to ensure adherence to set specifications and standards. b) Absence of record-keeping
4	Inadequate due process	a) Failed to thoroughly examine any unexpected variation in batch to meet any of its specifications b) Failed to follow required lab control methods and to document and justify any variations c) Not making sure test methods are sound from a scientific standpoint
5	Issue of integrity:	Firm continuously postponed, rejected, restricted, or refused to allow the FDA to inspect it.
6	Data irregularity:	When the procedure was carried out, the person listed as the supervisor was absent.

Table.3 No. of Warning Letters from 2019-2024[25]

Year	No. of Warning Letters
2019	15103
2020	5528
2021	2504
2022	17351
2023	14841
2024	13307





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Table 4 No of Injunctions and seizures from the year 2019-2024 [25]

Year	Injunctions	Seizures
2019	8	2
2020	8	0
2021	6	2
2022	6	0
2023	5	0

Table .5 Recalled products by Fiscal Year 2019-2024[26]

Year	Recalled Products
2019	7894
2020	7253
2021	5309
2022	5862
2023	6219
2024	6524

Table 6 Recalled Products by Product type by fiscal Year 2019-2024 [26]

Recalled Product Types	Fiscal Year (2019-2024)
Drugs	7338
Biologics	867
Devices	2820
Food/ Cosmetics	1941
Tobacco	1
Veterinary	482

Table 7 Recall Events by Product type Fiscal Year 2019-2024 [26]

Product Types	No. of Recall Events
Devices	15718
Drugs	7339
Food/Cosmetics	9405
Biologics	3678
Tobacco	2
Veterinary	1331





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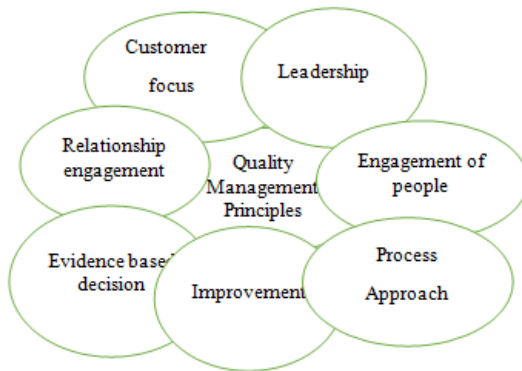


Figure : 1 Quality Management Principles [12]

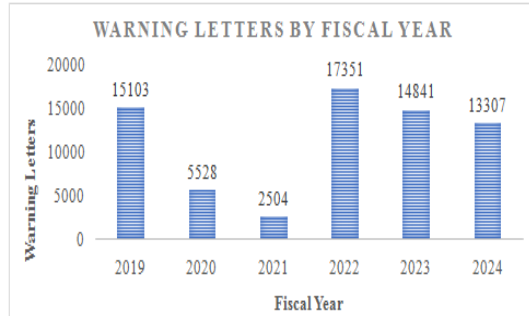


Figure : 2 Statistical Representation of Warning letters from 2019-2024 [25]

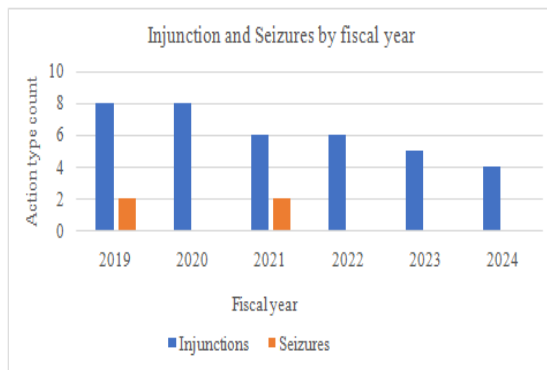


Figure: 3 Statistical Representation of Injunctions and Seizures by fiscal year 2019-2024 [25]

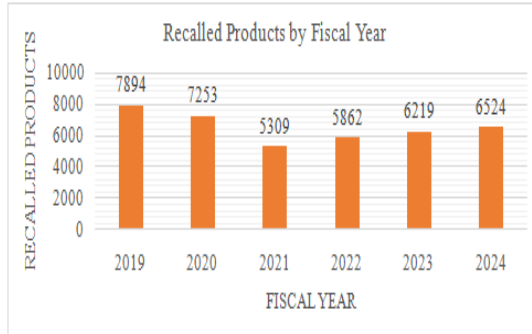


Figure : 4 Statistical Representation of Recalled Products by Fiscal Year 2019-2024 [26]

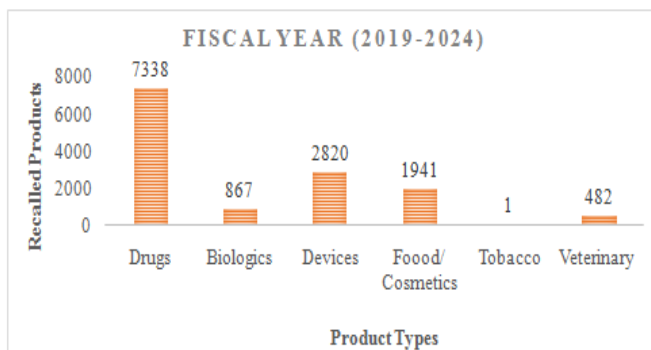


Figure : 5 Statistical Representation of Recalled Product Types by Fiscal Year 2019-2024 [26]

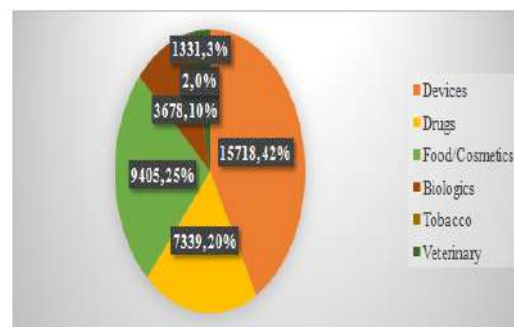


Figure :6 Statistical Representation of Recalled events by Product Types 2019-2024 [26]





RESEARCH ARTICLE

Agri-Tourism and Sustainable Farming: A Synergetic Approach for Rural Development and Environmental Conservation

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ABSTRACT

Agri tourism, the fusion of agricultural and tourism, has emerged as a promising strategy for promoting sustainable farming practices with simultaneous contribution to rural development and environmental conservation. It refers to the practice of opening agricultural operations to visitors, allowing them to engaging in farming activities, experiencing rural life and connecting with the source of their food. Sustainable farming on the other hand, encompasses agricultural practices that prioritize environmental stewardship, economic viability and social equity. This paper explores the dynamic relationship between Agri - tourism and sustainable farming, shedding light on their mutual benefits, challenges and the potential they hold for reshaping rural land scape worldwide through case study analysis of Agri tourism in India.

Keywords: Sustainability, Agri – Tourism, sustainable farming, Doubling farmers income.

INTRODUCTION

Agricultural tourism refers to the opening of agricultural enterprises to tourists, the participation of tourists in agriculture, experiencing rural life and establishing a bond with food. Permaculture includes agriculture, which is important for environmental protection, economic sustainability and social well-being. In a world grappling with the needs of a resilient food system, rural revitalization and natural resources, the interplay between these two seemingly contradictory elements is vital. Agricultural tourism provides additional income to farmers, reducing their dependence on traditional agriculture. This economic diversification can improve the financial stability of agriculture, making it more resilient to economic changes. Visitors to agritourism destinations can understand permaculture practices. This course raises awareness of the importance of the environment, local agriculture and



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health. Agritourism can help preserve rural culture and cultural heritage as visitors learn about the unique traditions, food, and lifestyle of communities. Permaculture practices such as organic growth and integrated management are often promoted in agritourism areas. This contact promotes the use of environmentally friendly technologies and helps protect soil, water and biodiversity. It is important to fight to balance the economy and control the reality of agriculture. Too much commercialization can lead to changes in rural life, which can lead visitors away from real farming. Creating a suitable system for agriculture, including hospitality and business ideas, can be a valuable resource for farmers. Cooperation with local governments and tourism organizations is required. If not managed properly, the influx of tourists can impact the environment. Strategies to reduce the ecological footprint of agritourism operations are important. This article provides case studies from different regions that demonstrate that successful agritourism is a useful first step towards permaculture practices

LITERATURE REVIEW

Agricultural tourism, Agriculture with tourism A multi-faceted concept that integrates, it is gaining widespread attention as the promotion of permaculture practices (Ammirato. ;2014). This literature review presents key findings from relevant studies and sheds light on the relationship between agriculture and permaculture (Barbieri; Mshenga. ;2008). Many studies have demonstrated the potential of agriculture in diversifying farmers' income and increasing the economic importance of rural areas. Income from tourist activities such as farm tours, self-collection and on-site sales increases farm income and reduces dependence on agriculture (Nickerson N.P.; Black R.J.; McCool;2001). Environmental sustainability is the foundation of permaculture. Agritourism provides a platform for promoting environmentally friendly agricultural practices such as organic farming, reducing pesticide use and soil conservation. This exhibition encourages visitors to appreciate responsible agriculture (Chang J.; Gerrish S.; Wang). Agricultural tourism can play an important role in preserving agricultural biodiversity. Agritourism provides a better understanding of the importance of biodiversity in agriculture, encouraging farmers to adopt practices that support community health (Campbell J.M.; Kubickova M.;2020). Soil health and water conservation are important aspects of permaculture. Data show that agricultural practices often include sustainability of soil and water management, reducing tillage, cover crops, and promoting efficient water use (Das B.R.; Rainey;2010). Community participation is critical to the success of agritourism businesses. Research shows that involving local people in agricultural production strengthens relationships and strengthens culture (Valdivia C.; Barbieri;2014). Agritourism can increase food security by encouraging local food production and consumption. Research shows that tourists who love local products can boost local businesses and support small farmers. Climate change poses serious challenges to agriculture (Wilson J.; Thilmany D.; Watson P;2014). Agritourism is a platform to promote agricultural adaptation to climate change, including drought-resistant crops and adaptation strategies. Agritourism often provides opportunities for women's participation and empowerment (Tew C.; Barbieri C). Research shows that women play an important role in farming and agriculture, contributing to family income and decision-making processes. Agritourism diversifies income, increases economic activity and supports rural development. It is also an educational tool to raise awareness of permaculture practices among visitors (Yang L.;2012). Agritourism contributes to environmental sustainability by promoting biodiversity conservation, responsible land and water management, and climate protection. Community engagement, including women's participation, can strengthen rural relationships and strengthen local communities (Iancu T.;2020). Additionally, agritourism increases food security by encouraging local food production and consumption, ultimately supporting the local economy. However, it is important to be aware of the challenges presented by agritourism, including balancing business with managing the reality of agriculture, managing the impact on the business environment, and investing in infrastructure and business investments (Sharpley R ;2007). Despite these challenges, the literature supports the idea that agriculture is a good strategy for promoting culture while benefiting rural communities and the environment (Yang L;2012).



**Varanasi Rahul et al.,****Case Studies****Sustainable Agri Tourism in Maharashtra**

Maharashtra is a major state in Western India where new models of agritourism are emerging, aiming to promote cultural practices while offering rural experience to audiences. Rural Odyssey, an agritourism project known for its commitment to sustainability, economic sustainability and community engagement, is a major research project. At the heart of Country Odyssey is its commitment to permaculture practices. The project is located on a farm where visitors can witness first-hand the use of good environmental strategies such as organic farming, pesticide use and water management. One of Rural Odyssey's main goals is to diversify the income of local farmers. By opening their farms to visitors, local farmers can reduce their dependence on traditional agriculture and create additional resources. Rural Odyssey offers visitors a variety of experiences including farm tours, farm work and interaction with the local community. These experiences provide visitors with a hands-on experience while encouraging an appreciation of rural life and agriculture. A key feature of Country Odyssey is its commitment to community engagement. The program actively involves the local community in every aspect of the farm, from leading tours to preparing meals for guests. This approach improves community relations and empowers local residents. This project attaches great importance to the protection of biodiversity. Visitors can explore the farm's many animal and plant species, and courses demonstrate the role of biodiversity in permaculture. Rural Odyssey includes environmental sustainability measures such as rainwater harvesting, composting and waste reduction. These practices both reduce the ecological orientation of the project and become an educational tool for visitors. Rural Odyssey has had a positive impact on the local economy. It created employment for local people, increased farmers' income and contributed to the growth of the local economy. Like many agritourism ventures, Rural Odyssey faces the challenge of balancing business with the reality of managing and managing the environmental impact of the business. However, its commitment to sustainability and community engagement is key to its success. Rural Odyssey is a shining example of entrepreneurship in the Indian state of Maharashtra. By combining environmentally friendly agriculture with social participation and public awareness, it provides ample income to farmers as well as supporting urban development and environmental protection. This research demonstrates model agriculture's potential to support permaculture practices while supporting local businesses and strengthening Indian communities.

Sustainable Agri-Tourism in Odisha

Odisha is a state in eastern India and is home to Chilika Lake, Asia's largest lake and a place of biodiversity. This case study examines Chilika Fresh, an innovative agricultural program in Odisha that not only promotes groundwater production but also enhances the tourism experience of tourists. Chilika Fresh is based on the principles of the aquaculture industry. The program focuses on sustainable agriculture, emphasizes responsible management, reduces pesticide use and reduces environmental impact. One of Chilika Fresh's main goals is to distribute revenue to local fishermen and aquaculture farmers. By integrating agritourism into their activities, they obtain a stable source of income beyond fishing. Chilika Fresh offers visitors a variety of activities such as boat tours, fishing experiences and shrimp farm visits. These experiences not only teach visitors about healthy aquaculture, but also allow them to experience coastal life. The program actively engages the local community in its work. Fishermen and their families are involved as leaders and owners, improving and sustaining their livelihoods through meaningful participation. Chilika Lake is famous for its diverse ecosystem. The program's training and tours emphasize the importance of biodiversity conservation in the context of aquaculture and wetland conservation. Chilika Fresh incorporates environmental practices including water quality management and recycling. These practices are consistent with the project's commitment to minimizing environmental impact. The project had a positive impact on the regional economy. It creates jobs, increases local income and supports local economic growth. Chilika Fresh faces many challenges, such as managing the balance between water resources and tourism, as well as solving environmental problems associated with the increasing number of visitors. Despite these difficulties, it has become a successful model for the integration of the aquaculture sector with agriculture. Chilika Fresh's case study shows how agritourism plays an important role in supporting healthy aquaculture while encouraging visitors to travel. Promoting responsible management, community participation and biodiversity conservation, the program not only diversifies fishermen's income but also supports the protection of important coastal ecosystems.



**Varanasi Rahul et al.,****Agri - Tourism Kerala**

Odisha is one of the eastern Indian states that is home to Chilika Lake, Asia's largest lake and a diverse cultural centre. This case study examines Chilika Fresh, an innovative agricultural program in Odisha that not only promotes groundwater production but also enhances the tourism experience of tourists. Chilika Fresh is based on the principles of the aquaculture industry. The program focuses on sustainable agriculture in terms of managing resources, reducing pesticide use and reducing environmental impact. By integrating agritourism into their activities, they obtain a stable source of income beyond fishing. Chilika Fresh offers visitors a variety of activities such as boat tours, fishing experiences and visits to the shrimp farm. These experiences not only teach visitors about healthy aquaculture, but also allow them to experience coastal life. The program actively engages the local community in its work. Fishermen and their families are involved as leaders and owners, improving and sustaining their livelihoods through meaningful participation. Chilika Lake is famous for its diverse ecosystem. The program's training and tours emphasize the importance of biodiversity conservation in the context of aquaculture and wetland conservation. Chilika Fresh incorporates environmental practices including water quality management and recycling. These practices are consistent with the project's commitment to minimizing environmental impact. The project had a positive impact on the regional economy. It creates jobs, increases local income and supports local economic growth. Chilika Fresh faces many challenges, such as managing the balance between water resources and tourism, as well as solving environmental problems associated with the increasing number of visitors. Despite these difficulties, it has become a successful model for the integration of sustainable agriculture with agriculture. Chilika Fresh's case study shows how agritourism plays an important role in supporting healthy aquaculture while encouraging visitors to travel. By emphasizing responsible management, involving local communities and promoting biodiversity conservation, the program not only diversifies fishermen's income but also contributes to the protection of important coastal areas.

CONCLUSION

Agritourism is a wonderful and evolving concept that promotes culture while encouraging remote development. The city, environmental protection and tourist education are very good. This research in agriculture and permaculture reveals numerous benefits, challenges and opportunities. In this concluding section, we present the key findings and insights from the case study and literature review, highlighting the synergies between agritourism and permaculture. One of the most successful aspects of agriculture is the ability of farmers to diversify their income sources and reduce dependence on agriculture. This funding gap can support rural communities, strengthen local businesses and contribute to overall rural development. Case studies such as 'Rural Odyssey' in Maharashtra and 'Spice Village Farm' in Kerala exemplify how the agritourism industry can bring significant economic benefits to rural areas. Permaculture practices are at the heart of agritourism and this partnership provides a strong platform for the dissemination of environmentally friendly technologies. From organic farming to responsible resource management, agritourism services often engage guests in discussions about permaculture. This course develops knowledge of food production and nutrition. "Chilika Fresh", which promotes groundwater production in Odisha, is a good example. Community participation is critical to the success of agritourism businesses. Collaborating with local people as guides, hosts and participants not only enhances their sense of ownership but also helps preserve heritage and culture. "Chilika Fresh" actively engages with the community in its work to support fishermen and their families. Agritourism plays an important role in promoting on-farm biodiversity conservation. Visitors can learn firsthand the importance of managing various ecosystems and the knowledge that often translates into sustainable agriculture. Rural Odyssey demonstrates the positive impact of agritourism on biodiversity conservation. Rapid climate change causes serious problems in agriculture. Agritourism helps farmers become stronger against climate change by promoting climate-smart practices and adaptation strategies. This dimension is especially evident in Chilika Fresh, which has introduced aquaculture to adapt to climate change. Agritourism initiatives often challenge gender roles in agricultural communities by providing opportunities for women's participation and empowerment. Women are involved in all areas of agriculture, contributing to family income and decision-making processes. In summary, the combination of case studies and literature review demonstrates the synergy between agritourism and permaculture.





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Agritourism diversifies income, strengthens rural communities and promotes environmental stewardship. This way visitors get a good idea of permaculture and immerse themselves in a real rural experience. Stakeholders, including farmers, policy makers and tourism officials, need to work together to realize this partnership. Addressing issues such as precisely measuring work and managing environmental impacts remains important. Additionally, continuous research, innovation and knowledge sharing are important to expand the boundaries of agriculture and make it more profitable for permaculture, urban growth and education for visitors. Going forward, the integration of agritourism and permaculture holds great promise not only in India but also globally. It advocates planning for shared economic success, environmental protection and community strengthening, the path to a better and stronger agriculture in the future. Agritourism and permaculture journeys are a continuation of farmers, communities and visitors' commitment to responsibility and change.

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Accessorial Nuisances by Avian Species at open Dumping Site: A Case Study

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ABSTRACT

The open disposal of biodegradable waste may not appear immediately harmful, yet it presents significant long-term environmental risks. Such practices can lead to nuisances, including foul odors and the spread of infectious materials by vectors like flies and birds. Historically, dumping sites for organic waste have attracted scavenger birds, and with ongoing urbanization, waste generation has increased considerably. This study examines the relationship between humans and birds near an open solid waste dumping site in Arambagh Municipality, West Bengal, India, adjacent to the Darakeswar River (22.8765° N, 87.7910° E). The predominant bird species observed include the house crow (53%), common myna (20%), and pied myna (19%), with fewer eastern great egrets and jungle babblers. Bird populations fluctuate throughout the day, with over 46% foraging in the early morning and about 40% in the afternoon. Additionally, a local survey reveals significant shortcomings in solid waste management practices. Some residents report skin diseases, underscoring the public health risks posed due to pathogens spread by birds and other vectors. There is an urgent need to implement alternative waste management strategies to mitigate these risks.

Keywords: Avian, open-dumping, biodegradable, nuisances, solid waste



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INTRODUCTION

Throughout global activities, humans have intentionally and unintentionally changed the biosphere. The vital factors impacting the current environment are the predictable food waste generated by humans and consumed by animal species, particularly birds, from garbage dumps. Solid waste generation is mostly an urban issue, but it is even worse as urbanization is increasing faster. The production rate of daily waste is not expected to diminish in the coming decades, as the degree of concern about this issue is minimal. As the reports reveal, just before the century out, the trash produced each day would be more than 11 million tons, up from the current global average of 3 MT per day. The start of this century is expected to mark the peak of garbage production [1-5]. It's anticipated that this excessive waste production will worsen ecosystem changes and create biodiversity shifts. It is interesting to note that the recycling rate of some countries has increased from 2% to over 90% in 20 years after banning direct land filling of waste in 2005. China, Japan, Malaysia, and Thailand, have also implemented laws to manage waste [6-8]. This presents an opportunity to transition from simple waste management to energy production through waste recovery and recycling programs. Birds play a vital part in ecosystems by dispersing seeds, controlling pests, and pollinating flowers. In addition to helping with nutrient exchange, migratory birds are hunted for food and recreation in several regions of the world. [9,10]. Birds first appeared around 165-150 million years ago whereas the appearance of modern human dates back nearly 200,000 years, but synthetic plastic was only invented in 1907, with mass production starting in the 1950s [11,12]. By 2050, global plastic production had exceeded yearly 800MT, with 79% of it ending up in the environment, including 1,610Lac tons of packaging waste alone.

Plastic is now recognized as a significant feature of the anthropogenic because of its connection to human action. Artificial waste that resembles natural food can have a detrimental impact on wildlife. The intestines of pet birds for example have been reported to trap rubber, which may be fatal if it obstructs food passage [13-15]. There is evidence that wild birds also eat rubber bands; in fact, rubber bands were discovered in the digestive systems of 26% of dead cranes. In West Sussex, ducks were rescued after consuming red balloons, thinking they were worms. This problem was caused by rubber bands used for bundling mail being washed away during rainstorms and ending up in the lake, where they were misguided to be food by birds [16-18]. The Swachh Bharat Mission, initiated in 2014, aims to provide sanitation facilities, including toilets, and implement scientific waste collection, processing, and disposal methods for every household. However, about 30% of the Indian population resides in urban areas[19,20]. India belongs to the list of top ten countries in creating MSW (municipal solid waste) over 65 million tons of garbage annually, with over 62 million tons being MSW (organic waste, recyclables such as paper, plastic, wood, glass, etc.). The collection of municipal waste in India is not up to the mark and of that, only 22-28% is processed and treated. The rest is disposed of in dump yards. It is reported that by 2030, 165 million tonnes waste will be generated, and this number will increase to 436 million tonnes by 2050. To manage solid waste properly with this growing amount of waste, the efficiency of waste collection in India needs to improve. Currently, collection of waste varies from 70 to 90% in major metropolitan areas, but is less than 50% in many smaller towns [21,22]. This study focuses on the existence of common birds at an open waste dumping site on the bank of the Darakeswar River in Arambagh. Additionally, the study includes the opinions of local residents regarding the problems associated with waste dumping and the presence of birds and other pests. The study will emphasize the conflicts between birds and humans as open dumping sites can attract avifauna while also causing disturbances to humans.

MATERIALS AND METHODS

Study Area

Our study area is the only open disposal site situated within the jurisdiction of Arambagh Municipality, Hoogly (22°53'19.0" N, 87°46'39.7" E), West Bengal, India, beside the Darakeswar River (Shown in Figure 1 and 2).



Sauvik Bose *et al.*,**field survey and collection of data**

Field visits were conducted from 7:00 am to 9:00 am, 12:00 pm to 2:00 pm, and 5:00 pm to 6:00 pm every other day from May to July 2023. Additionally, face-to-face interviews with local people were done to guess the link between solid waste and birds. Furthermore, in-person interviews with community members were conducted to evaluate the effects of solid waste management and bird-related concerns.

Mathematical Tool

The Shannon diversity index (H) is used to evaluate species diversity in a community, evaluating the evenness and abundance of the species present.

$$\text{Shannon Index (H)} = -\sum_{i=1}^S P_i \ln P_i$$

where S is the total number of species and P_i is the percentage of individuals in the i th species out of all individuals.

RESULTS AND DISCUSSION

On and near the dumping ground, five species were found. Their distinguishing characteristics are documented in Table 1. House crow were the most commonly found birds at the dump site while Jungle babbler was only a few in number. We observe that bird occurrences fluctuate throughout the day. 46% of the birds typically appear in the early morning to collect food, while around 40% are noted in the afternoon. However, the number decreases (14%) noticeably as the sun sets in the west. Distribution of the occurrence of birds (%) and Shannon diversity index is presented in Table 2. The Simpson's index (D) indicates good diversity at approximately 0.36, while the Shannon entropy of 1.22 suggests a higher level of entropy in the occurrences of birds, as shown. From field survey it was noted that some wastes attract birds for feeding (Table 3). Interaction was initiated with individuals residing near the dumpsite during our survey. The information gathered is cited in Table 4. Figure 3 shows the relation among humans, birds, and other vectors carrying pathogens encircling open solid waste dumping. Open dumping has a positive impact on the diversity of birds, as seen in field results, but it also poses a threat to human health and living.

CONCLUSIONS

The two possible functions of birds in the dumping sites could be, one is the roles of scavengers to eat up the organic (mostly fleshy) wastes which are very prone to grow microbes; the second one might be consumption of some vermin and other macro populations growing at the dumping grounds. Though we did not observe scavengers, the first purpose is not pertinent to this field, but the second one is quite relevant. Since the dwellers do not have a remarkable issue related to any of the vector-borne diseases. It is conceivable that the birds at open dumping sites help to control the growth of macro and micro-organisms. However, these birds and other vectors can also spread infections, which is a significant issue in tropical countries. To prevent this, it is important to implement alternative waste management methods, as open dumping has numerous negative effects on our environment and also human health. Currently, our country has introduced various systems to disinfect, recycle, and reuse MSW in different areas. However, the question remains: while dumping yards undoubtedly support avian populations, they are also sources of pathogenic infections. If the country can successfully process a large proportion of MSW in the coming decades, some avian species might disappear from our surroundings. In this conflict, preventing the spread of infections should be the top priority. One potential solution to attract birds is to place feeders or feeding bowls on windowsills.

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Table 1: Identifying Characteristics of Birds

Common Name	Scientific name	Identification
House crow	<i>Corvus splendens</i>	Glossy black, the neck and breast are a lighter grey in colour. The wings, tail and also legs are black.
Common myna	<i>Acridotheres tristis</i>	Brown body and Black hooded head. The bare yellow patch behind the eye. The bill and legs both are bright yellow
Pied Myna	<i>Gracupica contra</i>	Yellowish bill, an orange base and black upper parts, white belly and white rump.
Eastern great egret	<i>Ardea alba modesta</i>	White in color. Yellowish-orange bills, and the legs black.
Jungle babbler	<i>Turdoides striata</i>	plain-looking babbler with a compact built and conspicuous pale eye

Table 2: Occurrences of birds on the dumping ground and diversity index

Name	Population	Simpson's index	Shannon Entropy
<i>Corvus splendens</i> (House Crow)	53%	0.36	1.22
<i>Acridotheres tristis</i> (Common myna)	20%		
<i>Gracupica contra</i> (Pied Myna)	19%		
<i>Ardea alba modesta</i> (Eastern great egret)	5%		
<i>Turdoides striata</i> (Jungle babbler)	3%		

Table 3: Types of waste

General wastes (non-attracting)	Wastes attracting the birds
Paper, wood, plastics, glass, metals, medicine strips, stones, ceramics, leathers and so on.	Kitchen waste, grass, fruits- seeds and peels, husks, grains, rodents, dead animal parts etc

Table 4: Information from face to face interview

Parameters	Information
Sex Ratio	Male: 80% and Female: 20%
Age Group	10yrs-15yrs: 20% 15yrs-25yrs: 10% 26yrs-59yrs: 50% 60yrs+: 10%
Occupation	Government employee: 10% Private employee: Nil Business/Entrepreneur: 10% Student: 40% Housewife: 10% Retired: Nil Other: 30%
Duration of staying at that place	Greater than 10yrs



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Whether knowing MSW	Yes: 10%, No: 90%
Mode of disposal of daily household wastes	Gather the waste in a bucket and throw that waste in the dumpsite.
Distance from the dumping site	Around 400m
Nuisance because of open dumping	During the monsoon and rainy days, bad smell comes from the dump site.
Whether the local authority responsible enough to manage solid wastes	Yes: 70%, No: 30%
Health issues	Sometimes skin irritations and skin diseases occur to the family members beside no other big disease occurred as of now.
Whether birds are one of the major factors in increasing trouble	Yes: 85%, No: 15%



Figure 1: Photograph of study area



Figure 2: Two-dimensional view of study area (source: google map)

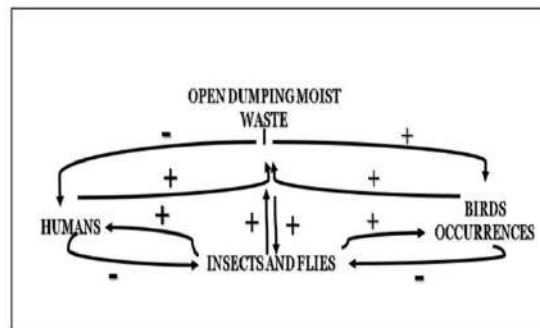


Figure 3: The feedback loop shows the relations





RESEARCH ARTICLE

Economic Empowerment of Women and Sericulture : A Socio-Economic Study of Ranibandh Block of Bankura District, WB, India

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ABSTRACT

Sericulture, an agro-based industry, employs many women and elderly people, with their skilled and unskilled labours. Silkworm rearing is very sensitive and delicate work especially during later instar where the rural women are suitable for the work. It is impossible to sustain their ongoing daily needs solely through agriculture. Data on the rearing performance of Daba eco-race Tirvoltine DTV-1, DTV-2, and DTV-3 Tasar silkworms in the villages of Baroghutu and Harangara in Khatra Block were gathered and analyzed for the following years: 2014–15, 2015–16, 2016–17, and 2017–18. The post hoc analysis reveals that both DTV-I and DTV-II differ significantly from DTV-III ($p < 0.0.1$) in case of the total number of groups cultivated them. Significant differences between various sericulture-related parameters in Baroghutu and Harangara villages were observed. The net income (NI) of farmers in Harangara village was markedly higher than that of farmers in Baroghutu village, as evidenced by an F-value of 7.762 ($p < 0.01$). The purpose of self-help groups are to prevent economic marginalization, empower one another,



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and confront common social and economic challenges. Because of this, "Tasar" culture can support year-round, sustainable economic growth. Therefore, it is possible to view sericulture as a crucial tool for the empowerment of rural women to raise the standard of living for their entire family, the village, and bioresource management. Here, appropriate administration and a variety of self-help groups can be crucial to the empowerment of rural women.

Keywords: Baroghutu; eco-race, empower, Harangara, rural, Sericulture, Tasar silk worms, women

INTRODUCTION

Sericulture or silk farming is a promising agricultural business that has the ability to boost the farming community's economic standing and also generating foreign revenue [1]. It is positioned as a means of improving farming communities' economic standing. Farmers can diversify their income sources by engaging in sericulture, potentially lowering their reliance on single crops and enhancing overall financial stability. Sericulture allows those with little skills or resources to participate in meaningful economic activities. This inclusion of less-skilled and underprivileged members of society has the potential to result in more equitable development. More than 58 countries of the world practicing sericulture but only in India where all four varieties of silk are cultured [2]. On global scale Asian countries contributes 95% of the total silk production and contributes a leading role in sericulture industry. [3] According to International Sericultural Commission (2021), India and China are major silk production countries subsequently followed by countries like Japan, Brazil, Uzbekistan and Republic of Korea [5]. Sericulture, a labour-intensive industry, currently employs about one million people in China's silk sector. In India, around 7.9 million people were connected directly with silk industry, whereas 20,000 weaving families were engaged with sericulture industry in Thailand [4]. More than 1.5 lakh rural tribal people in the Indian states of Bihar, Andhra Pradesh, Jharkhand, Uttar Pradesh, Chhattisgarh, Maharashtra, West Bengal and Orissa heavily dependents on this agro-based cottage industry. This industry's relevance extends beyond economic contributions, as it is critical to the livelihoods and cultural legacy of these regions. Sericulture provides various benefits to these rural communities, including job creation, skill development, income diversification, female empowerment, and the preservation of traditional practices. Silkworm rearing involves several stages, from mulberry cultivation to silk processing, allowing a variety of chances for individuals to participate in various sectors of the industry. Sericulture is also compatible with the cultural and traditional fabric of these states, and is frequently incorporated into local customs, festivals, and rituals.

This intimate relationship highlights its importance in conserving and fostering cultural history, making it more than just a business but also a symbol of identity [6]. As per silk production estimates of total raw silk production of 30,348 MT, 70.10% of silk production comes from mulberry while non-mulberry silk production measured for 10.77%, 18.57%, and 0.56%, respectively silk in the year of 2016-17 [7,8, 9]. Host plant of tropical tasar (*Antheraea mylitta*) is mainly Asan (*Terminalia tomentosa*) and Arjuna (*Terminalia arjuna*) forests of central and north-eastern India, which is found commonly in the states of Bihar, Jharkhand, Chhattisgarh and Andhra Pradesh. Maharashtra, Telangana, Odisha and West Bengal, provides sustainable livelihood to rural tribal communities [7]. Jharkhand is the largest tasar silk producer state in terms of quantity of India with production reaching 2217 MT in 2017-18 subsequently followed by Chhattisgarh, Odisha, and Bihar follow, while West Bengal produces 35 MT of raw tasar silk and ranks fifth among other states [7]. Purulia, Bankura, and Midnapore, which are considered tribal dominated areas of West Bengal state, contribute significantly to the production of tasar silk [5]. Women workers contribute one-third of the global labour force and give nearly two-thirds of total working hours, yet their contribution to crucial productive work-share remains unnoticed [10]. In India approximately 12.7 crore women work as women labour, with majority of them working in unorganized sectors. They are employed particularly as marginal and casual agricultural jobs, where the gender wage disparity is prominent [11]. Women in India are also engaged in agro-based home chores, where they often serve as unpaid family labour and hence go unnoticed.



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Sericulture is one of such field where majority of the work is done only by the women. Thus, they can play a very significant role in the activities spectrum as well as in decision-making in household business [10]. Women's contributions to sericulture have been neglected throughout history. They can play a significant role in various stages of the sericulture industry, from rearing silk-producing worms through processing and weaving silk [12]. The caring nature of a woman depicts very significantly by the way they take care of creating an appropriate habitat for the silkworms, assuring proper feeding, and safeguarding them from infections. This delicate and detailed activity necessitates precise care, patience, and attention to detail, all of which women have constantly displayed. In addition women played an important role in delicately unravelling the silk threads from the cocoons once the silkworms have made cocoons. Women have long been noted for their ability to perform this intricate chore with ease, passing down information and techniques from generation to generation.

AIMS AND OBJECTIVES

The paper makes a modest effort to present a picture of Bankura District's female workers in the sericulture industry and account for the predominance of female workers in sericulture farms in West Bengal. Comparative studies of the possibilities, cost effectiveness, and man-day generation by rearing of different silkworm varieties were also conducted. This paper will also attempt to shed some light on the role of self help groups (SHG's) for encouraging women to join in sericulture practices and also diagnosing how sericulture might help to improve the socioeconomic status of underprivileged tribal families

Present status of sericulture in Bankura district

Bankura district has a long history of sericulture. Bankura district contributes main silk production zone of West Bengal. The district's sericulture industry mainly divided into mulberry and tasar sectors. Tasar silk is mostly reared by tribal people in the district's southern and western regions. The majority of the blocks of this district are engaged with tasar cultivation, with only a small (276.50 acre) portion to mulberry silk cultivation. The majority of the Barjora, Bishnupur, Patrasayer, Kotulpur, Onda, Simlapal, Saltora, and Taldangra blocks exhibit mulberry sericulture, although there is no post cocoon activity. 14 of the district's 22 blocks are involved in tasar sericulture. Only 5 blocks are participating in post-cocoon activity (Table 1) [13]. Tribal people of this district have a long-standing custom of raising tasar silkworms in natural forests. Tasar silkworm rearing in natural forest flora like Arjun (*T. arjuna*), Asan (*T. tomentosa*), Sal (*Shorea robusta*), and Sidha (*Lagerstroemia parviflora*), is a traditional activity among the tribal people since time immemorial as a part of their tribal culture. Grainage units have been established in different blocks in order to preserve and offer high-quality, disease-free layings (dfls) to the rearers at a reduced cost. Since 1980, the district's Tasar host plantation (Arjun) has also grown significantly. Arjun has covered the hillocks and fallow ground that were the most unproductive desolate wastelands, giving the poor tribal people a means of subsistence and making it one of their main sources of revenue. Now a days by the use of more advanced technology, a continual improvement in and maintenance of the quality of disease-free layings (dfl) were observed. Tasar silk production covered 6972 acres of plantation space in 2017–18 and 13.36 MT of raw silk was produced [14]. Six out of the 14 tasar-farming blocks in Bankura account for 84.8 % of the region's total tasar cocoon production. The remaining 8 blocks account for only 15.2 % of the total production for the whole of the district. Maximum tasar silk production occurred from block Ranibandh (47.3%) taken after by Khatra (18.1%), Raipur (8.3%), and Hirbandh blocks (6.4%) [13]. Post cocoon activities were conducted in Bishnupur, Sonamkuh, Patrasayer (Banbirsingha), Khatra (Harangara) and Joypur blocks of this district. In 2014–15, PRADAN started work on the cultivation of tasar in West Bengal through the MKSP-NTFP programme of Mahila Kisan Soaktikaran Parishiyojana (PRADAN). The first year PRADAN worked with 480 families. By 2017–18, PRADAN had 2,066 tassel-based families engaged in the activities of Binpur-2, Ranibandh and Jhargram blocks in West Bengal. The concept of tasar based activities in group being a great initiative to bring villagers and stakeholders under the umbrella of a livelihoods group named Tasar Vikas Samiti (TVS) (Figure 1 & Figure 2).





MATERIALS AND METHODS

Study area

Two villages (Baroghutu and Harangara of Ranibandh Block which is about 90 k.m. from Durgapur and about 45 k.m. from Bankura) of Bankura district in West Bengal were chosen as the study area. Bankura district lies between 22°38' and 23° 38' N and 86° 36' and 87° 46' E (Figure 3 & Figure 4). Bankura can rightly be described as an intermediate zone with unique geo-climatic characteristics, lying between the plains of Bengal in the east and the plains of Chhota Nagpur in the west. A large part of the district is under forest cover of Arjun (*T. arjuna*), Asan (*T. tomentosa*), Sal (*S. robusta*) and Sidha (*L. parviflora*) and is inhabited by castes (>32%) and Scheduled Tribes (>10%). Agricultural productivity is weakened by low rainfall, dry weather and undulating terrain compared to other regions of the neighbouring municipalities. Monoculture is common in the region, where rice is the most popular crop. Due to the unfavourable climate and monoculture farming model, most farmers are tied to some secondary source of income. Being the tasar silk belt, thousands of farmers in that region opt for tasar silkworm rearing as a secondary source of income. Cultivation of trivoltine (TV) tasar silkworm *Antheraea mylitta* D. occurs in different areas of the region dominated by Arjun plant (*T. arjuna*).

Data Collection

Repeat visits were made in two selected villages where silkworm host plant cultivation, silkworm rearing and post cocoon activity were observed during the year 2015-16, 2016-17 and 2017-18 season. We purposefully selected these settlements because we knew there were several SHGs operating there, many of which were dependent on the forest for their raw supplies. According to the ease of accessibility and the presence of members at the time of the survey, the SHG members were chosen using a convenience sampling method. The necessary information was gathered in accordance with a schedule that was structured to compile each piece of information on the numerous ways SHGs work, engage in activities, and express opinions, among other things (Figure 5). The analysis involved a sample of 125 individuals from various SHG groups. Responses from local residents, government officials, sericulture farmers, winders, weavers and traders are recorded and analysed. Current reproductive practices and the production process are also critically examined.

Statistical analysis

Data processing and statistical analysis were thoroughly conducted using SPSS (Statistical Package for Social Science), a statistical software package. Analysis of variance (ANOVA) were conducted using continuous variables while chi-square test were conducted using categorical variable data. When the F value indicated statistically significant results ($p < 0.05$), to identify differences between pairs of means, Dunnett's post hoc test was conducted. Statistical significance was set at $p < 0.01$. Karl Pearson's bivariate correlation analysis was used to explore the relationships between the studied parameters. A rain cloud plot was generated using JASP 0.18.3.0, and an alluvial plot was created to demonstrate significant associations between categorical variables.

Missing value analysis

Neglecting the issue of missing data can lead to reduced statistical power of the models, biased parameter estimates, and erroneous conclusions about the studied phenomenon [15,16]. Expectation maximization (EM) method was applied to determine the missing data and imputed the data in this study. [17].

RESULTS AND DISCUSSION

In Bankura district, there are patches of forests where tasar host plants are naturally grown. In these areas, there are a large number of tribal people who depend on the forest for their livelihood and social well-being. Tribal communities of this region contribute to the growth and development of the tasar industry with their roots in tasar tradition and culture from ancient times. In these tribal dominated villages, Tasar plantation starts in 1981 and up to 2003 many barren lands were converted for tasar culture. Women were previously excluded from silkworm rearing.





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Traditionally, only tribal male members (including children) engaged in rearing silkworms in the forest. Women's involvement in the rearing of silkworms has proven necessary to overcome a major impediment to women's equal participation in sustaining livelihoods and to revive a sector in decline. Tribal women of Ranibandh block were more actively participated in tasar culture than other villages. Most of the villagers of these block were engaged with Tasar rearing and Disease free egg production and few were only engaged with rearing. In this paper, we have compiled and analyzed the data regarding the rearing performance of Daba eco-race Tirvoltine DTV-1, DTV-2, DTV-3 for the year 2014-15, 2015-16, 2016-17 and 2017-18 silkworm seed. Tasar silkworm rearing performance of Baroghutu and Harangara villages of Bankura District were collected and examined (Figure 6). Tasar silkworm rearing performance of Baroghutu and Harangara villages of Khatra Block during the years 2015 – 16, 2016 – 17 and 2017 – 18 of Daba eco-race of Tirvoltine (DTV) was collected, compiled and presented Table respectively. In Baroghutu Village, they select DTV-I type of crop but in Harengara they reared DTV-III type of crop and number of female member engaged in rearing in these villages' ranges between 23-36 members. Good quality cocoon of DTV-I type found in 2015-16 is 96295 but in next two years cocoon production decreases but DTV-III type cocoon production increases from 91520 in 2014-15 to 195840 in 2017-19 in Harengara. So a total of 21.32% increase of income through cocoon selling occur from 2015-16 to 2017-18 in Harengara but total earning decreases in Baroghutu village by rearing in DTV-I race. Highest number of Dfl/ cocoon yield was harvested in Harengara (1:104) and in Baroghutu it is 1:60. Duration of DTV-I type of crop rearing takes time 41-42 days whereas in Harengara DTV-III type of crop rearing takes 60 days.

In these study areas In 2014 to 2018 only 03 women groups were engaged with Daba eco-race Tirvoltine DTV-1 rearing and post cocoon rearing while interest of rearing were more in DTV-III rearing and 2014-15 only 12 groups were engaged with this type of rearing but it increases up to 17 groups and total man-day produced 9009 days where as in DTV-1 culture man-day produced ranges between 802- 2242 days in four consecutive years. DTV-I type Dfls were reared 2000number in 2014-15 and it increases upto 3000 in 2017-18. But in 2014-15 a total of 18450 number of DTV-III type of Dfls were reared which increases upto 28910 in 2017-18. The number of DTV-I type cocoon produced in 2014-15 was 45984 which increases upto 137684 in 2017-18. Similarly production of DTV-III type cocoon increases every year and in 2017-18 a total of 550200 numbers of cocoons produced in these areas. Similar types of observation were reported in Ghar Ghoda tribal block of Raigarh district of India [18]. So for the past two decades, the members have earned their income by Tasar rearing and reeling on an individual basis in these villages. But now, working in a group setting, these tribal women are able to earn their income in a better manner reducing the seasonal and forced migrations. There is a significant difference between the number of groups ($F=190.029$, $p < .001$) cultivated various species indicating a large variation attributed to the differences between the groups (Figure 7a). The ANOVA also shows significant differences (Figure 7b) between the CDG and species ($F=19.489$, $p < 0.01$). The between-groups sum of squares is 237.400, with a mean square of 118.700, while the within-groups sum of squares is 54.816, with a mean square of 6.091. This indicates that the variation between the groups is significantly greater than the variation within the groups. The post hoc analysis using Dunnett t-tests compares each group against the control group, DTV-III. The post hoc analysis reveals that both DTV-I and DTV-II differ significantly from DTV-III ($p < 0.01$) in case of the total number of groups cultivated them. For the CDG variable, only DTV-I differs significantly from DTV-III ($p < 0.01$), while the difference between DTV-II and DTV-III is not statistically significant.

Significant differences between various sericulture-related parameters in Baroghutu and Harangara Villages were illustrates in Figure 8. The net income (NI) of farmers in Harangara village was markedly higher than that of farmers in Baroghutu village, as evidenced by an F-value of 7.762 ($p < 0.01$). Additionally, the study highlights substantial differences in the number of cocoons (NC) ($F = 18.976$; $p < 0.01$) and the number of DFLs reared (NDR) ($F = 145.223$; $p < 0.01$) between the two villages. Furthermore, a significant year-on-year difference in the cost per man-day (CPM) was observed ($F = 4.987$; $p < 0.05$). Figure 9 elaborates significant association between the categorical variables. For Dfl by species, the distribution shows a significant difference ($\chi^2 = 8.914$, $p < 0.05$). DTV I and II primarily have ≤ 10000 dfls, whereas DTV III has > 10000 dfls. For Group by species, the chi-square test indicates a highly significant difference ($\chi^2 = 12.000$, $p < 0.01$). DTV I and II are mostly found in ≤ 10 groups, while DTV III is in > 10 groups. For Dfl by village, there is a significant difference ($\chi^2 = 8.400$, $p \leq 0.004$). Baroghutu predominantly has ≤ 10000 dfls, while Harangara has > 10000 dfls. For CPD by village, the distribution shows a significant difference ($\chi^2 = 6$, $p \leq 0.05$).





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Baroghutu has mostly normal CPD, whereas Harangara has a mix of low and normal CPD, with no high CPD. These results indicate distinct patterns in dfI rearing, group sizes, and cost per man-day between different species and villages, suggesting non-random distributions. The correlation matrix (Figure 10) provides insights into the relationships among variables. Each cell shows Pearson's correlation coefficient (r) and its corresponding p -value, indicating the strength and significance of associations. For instance, NDR is strongly negatively correlated with CDG ($r = -0.822$, $p < 0.001$), suggesting a robust inverse relationship. NC exhibits a strong positive correlation with both NDR ($r = 0.863$, $p < 0.001$) and TC ($r = 0.865$, $p < 0.001$), highlighting significant positive associations. Conversely, CD shows a weak negative correlation with NDR ($r = -0.468$, $p = 0.125$), which is not statistically significant at the typical alpha level of 0.05. These findings provide a nuanced understanding of how these variables interrelate in the dataset. Research shows that microfinance for the poor is easier, more efficient and less expensive if it is organized into self-help groups. Self-help groups are small, non-profit organizations of people from similar socio-economic backgrounds who share a common need or interest. They work together to solve social and economic issues by providing self-help, mutual empowerment and preventing economic marginalization.

CONCLUSION

In many countries of the world employment opportunities of rural women were restricted to low-skilled jobs. Sometimes women were exposed to unsafe working conditions. Now a day's women's participation in the labour force has increased a little bit despite many challenges. Women can play a vital role in natural resources management as well as restoration and preservation of the natural and man-made environment. Women have good understanding of the environment because rural women are mostly responsible for domestic and household management so they interact more with the environment. Agro based industry like sericulture has the potential to increase the job opportunities for rural people. It also empowering women and many women can take part in these activities and get benefit from it. Recently group-based approaches to poverty alleviation have become increasingly popular, particularly in the area of microfinance for the poor. Sericulture can help rural women under the umbrella of self help group can overcome various obstacles. Government and non government organization should come forward to access credit, education, and vocational training, thus increasing empowerment opportunities for rural people. Thus, it is possible to state that the sericulture sector has both potential and obstacles. For the development of the silk industry in this area, we require a well-thought-out plan with sensible policies for sericulture. So that many women in this area can take part in the plan and get benefit from it, It also helps to eradicate poverty of this region and ultimately lead to the district's overall upliftment.

Ethical approval (for researches involving animals or humans)

No Tasar cocoons were captured or killed or subjected to any experimental treatment during the study period.

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Table 1 : Block wise participation of Sericulture in Bankura District

Tasar Pre cocoon sericulture activity	Tasar Post cocoon sericulture activity	Mulberry Pre cocoon sericulture activity	No Pre cocoon sericulture activity
Bankura –I, Onda, Bishnupur, Borjora, Patrasayer, Taldangra, Simlapal, Ranibandh, Khatra, Raipur, Hirbandh, Chhatna , Sarenga, Indpur	Bishnupur, Sonamukhi, Khatra ,Patrasayer, Joypur	Onda, Bishnupur, Borjora, Patrasayer, Taldangra, Simlapal, Kotulpur, Saltora	Gangajalghati, Indus, Joypur, Bankura –II, Mejhia





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<p>Figure 1: Hands on training on Tasar rearing</p>	<p>Figure 2: Villagers took part in Tasar rearing</p>
	
<p>Figure 3 : Site map of Harangara Village</p>	<p>Figure 4 : Site map of Baroghutu Village</p>
	
<p>Figure 5 :Tasar cultivation in Baroghutu Village</p>	





Figure 6: Taking care of Tasar cocoon in Harangara Villllage

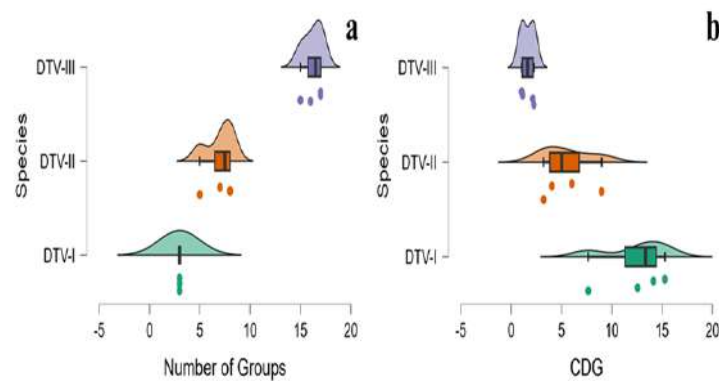


Figure 7a & Figure 7b: Variation of number of groups (a) and CDG (b) with species

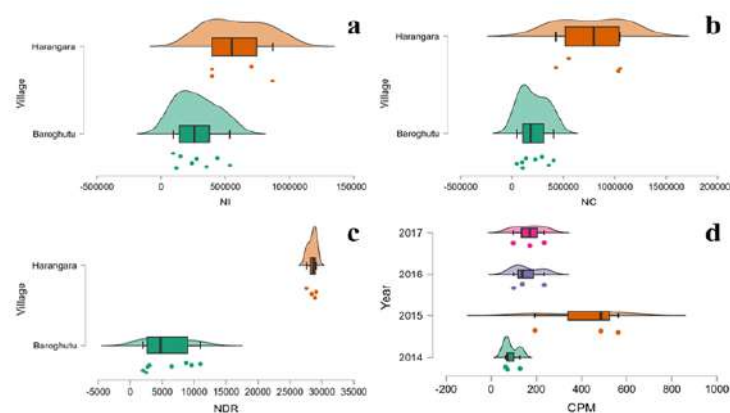
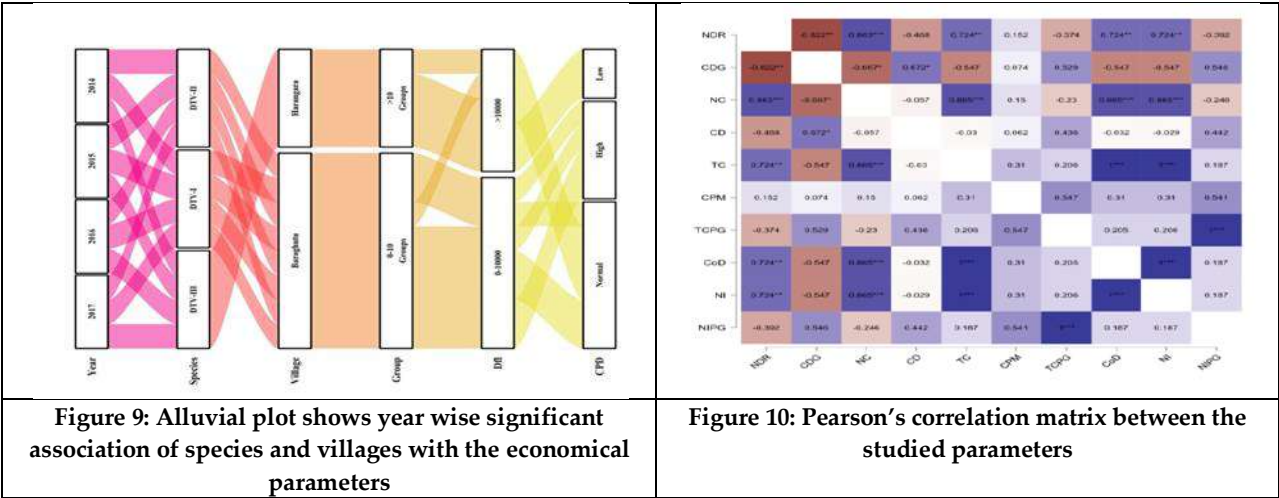


Figure 8:Village wise variation of NI (a), NC(b), NDR (c) and Year wise variation of CPM (d)





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NCR		0.521***	0.863***	-0.408	0.124**	0.162	-0.374	0.724***	0.724***	-0.388
CDG	-0.521***		-0.863***	0.408	-0.124**	-0.162	0.374	-0.724***	-0.724***	0.388
NC	0.442***	-0.547		-0.027	0.885***	0.15	-0.23	0.885***	0.885***	-0.240
CD	-0.442***	0.547	-0.027		-0.09	0.062	0.435	-0.885***	-0.885***	0.442
TG	0.724***	-0.724***	0.885***	-0.885***		0.31	0.205	***	***	0.187
CPM	0.152	0.074	0.15	0.062	0.31		0.547	0.31	0.31	0.541
TCPO	-0.374	0.374	-0.23	0.435	0.205	0.547		0.205	0.205	***
CoD	0.724***	-0.724***	0.885***	-0.885***	0.31	0.205	0.205		***	0.187
NI	0.724***	-0.724***	0.885***	-0.885***	0.31	0.205	0.205	***		0.187
NIPD	-0.388	0.388	-0.240	0.442	0.187	0.541	0.187	0.187	0.187	
	NCR	CDG	NC	CD	TG	CPM	TCPO	CoD	NI	NIPD





Data Envelopment Analysis for Estimating Efficiency of Hospitals: A Comparative Study using CCR and BCC Models

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ABSTRACT

This study compares two models in Data Envelopment Analysis (DEA) namely;Charnes, Cooper, and Rhodes (CCR) model and Banker, Charnes, and Cooper (BCC) model, with an emphasis on how the district hospitals in Madhya Pradesh, India, can use them. In operations research, decision-making units (DMUs) are evaluated for effectiveness using DEA, a non-parametric technique. While BCC model permits variable returns to scale (VRS), CCR model is predicated on constant returns to scale (CRS). In order to determine efficiency scores and benchmark performance, this study uses both models to assess the operational efficiency of district hospitals. We used data from a subset of Madhya Pradesh district hospitals for the 2019–2023 fiscal year. The number of beds, doctors, and health personnel (such as nurses, lab technicians, etc.) were among the input factors. The number of deliveries, maternal deaths, and infant deaths were among the output variables. The outcomes show that there are notable variations in the efficiency scores between the two models, underscoring the significance of scale efficiency in assessing hospital performance. The present study examines the consequences of these variations and offers suggestions to hospital administration and policymakers to enhance resource distribution and operational efficacy.

Keywords: Efficiency, Data Envelopment Analysis, CCR Model, BCC Model, District Hospital.





INTRODUCTION

A potent non-parametric technique called data envelope analysis (DEA) is used to assess the effectiveness of decision-making units (DMUs) that transform many inputs into multiple outputs. Since its introduction by Charnes, Cooper, and Rhodes in 1978 which assumes constant returns to scale (CRS) [1], DEA has gained widespread recognition as a useful instrument in performance evaluation and operations research. DEA compares the weighted outputs to weighted inputs ratio to determine the relative efficiency of DMUs. In contrast to conventional techniques, which call for predetermined functional forms and weights, DEA builds an efficiency frontier through linear programming. The best-performing units are represented by this frontier, which serves as a baseline for other units. A unit having an efficiency score of 1 is considered totally efficient. The efficiency value ranges from 0 to 1. Variable returns to scale (VRS) are supported by a particular formulation of Data Envelopment Analysis (DEA) known as the BCC model, named for its authors, Banker, Charnes, and Cooper [2]. Evaluating and comprehending the operational efficiency of the DEA CCR and BCC models in connection to Madhya Pradesh's district hospitals is the main goal of this comparison. Our goal is to distinguish between hospitals that are running efficiently and those that are not by calculating and comparing the efficiency ratings using both models. Comprehending the distinctions between the efficiency measurements of the CCR and BCC models—specifically, the assumptions of constant versus variable returns to scale—is essential for accurate evaluation. The study also aims to identify benchmark hospitals that establish the benchmark for efficient operations, offering guidance for underperforming hospitals. The study's conclusions will guide the best use of resources and point out areas where input-output ratios might be improved. The results will be used to inform the formulation of policy recommendations that will increase hospital efficiency by implementing techniques like process optimization and resource reallocation. In the end, the objective is to improve Madhya Pradesh's healthcare system by encouraging resource efficiency, guaranteeing improved patient care, and establishing the framework for DEA applications and healthcare efficiency research in the future.

ROLE AND IMPORTANCE OF DISTRICT HOSPITALS

In order to guarantee accessibility for the vast majority of the people, district hospitals are positioned strategically in each district headquarters. Within the district, these hospitals serve both rural and urban communities' medical requirements. District hospitals' bed capacities fluctuate based on the district's population and healthcare needs.

The district hospital is a crucial component of the health care delivery system in the three-tiered hierarchical level of public health care. It serves as a supplementary level of healthcare, offering the residents of the district complete preventive, promotional, and curative medical services. Public hospitals and health centres like the community health centre (CHC), primary health centre (PHC), and sub-centre (SC) are connected to each district hospital. District hospitals are required by the Indian Public Health Standards (IPHS) to:

1. offer the community complete secondary health care, including expert and referral services;
2. attain and keep a satisfactory level of care quality; and
3. Increase the responsiveness and sensitivity of services to the requirements of the local population as well as the hospitals and centres that send patients to them. In India, there are 810 district hospitals that offer vital services to the populace. Numerous health indicators have been taken into account in this study, such as the number of beds, the number of physicians, nurses, and paramedical personnel, the availability of diagnostic and medical specialties, and the rate of bed occupancy, among others. A comprehensive assessment approach was required to achieve the goals and objectives that guided the identification of the indicators. Under the structural and output domains, indicators were extensively categorized, and the best and worst performing district hospitals for each indicator were determined.

METHODOLOGY

DEA, a non-parametric method based on linear programming, evaluates the relative efficiency of homogeneous sets of DMUs utilizing various inputs to produce multiple outputs. It does not assume an explicit functional form but relies on basic assumptions about the underlying technology, allowing the construction of the production possibility





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set from observed data. By calculating scores that range from 0 to 1, which indicate their efficiency inside a linear programming approach, the DEA methodology allows to benchmark the best practice decision-making unit (DMU) [15]. Efficiency is defined as the ratio of input to output. But according to Sinuany-Stern et al. [16], the DEA frequently deals with a unit that has many inputs and multiple outputs. This study compares the efficiency scores of Madhya Pradesh's district hospitals using data envelopment analysis using the CCR and BCC models. DEA is a technique created by Charnes et al. [1] (also known as the CCR Model) that measures the technical efficiency of DMUs based on the efficiency frontier. If a DMU's efficiency rating is less than 1, it is regarded as relatively inefficient. The Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC) [2] models are the two fundamental models in the DEA approach. Although the BCC model relies on the premise that there is a variable return to the scale, the CCR model is predicated on the idea that there is a constant return to the scale.

DEA-CCR Model

The DEA CCR Model is defined as follow:

The efficiency of each DMU_o, Z_o, can be found by solving the LPP below.

$$Z_o = \max \sum_s v_s y_{so} \quad (1)$$

Constraints

$$\sum_k w_k x_{ko} = 1$$

$$\sum_s v_s y_s - \sum_k w_k x_{ko} \leq 0$$

$$v_s, w_k \geq 0$$

The dual of equation (1) can be used to find this sort of DMU. 2 defines the duality of (1).

$$\min e_o \quad (2)$$

Constraints

$$\sum_p \rho_p x_{kp} - e_o x_{ko} \leq 0$$

$$\sum_p \rho_p y_{sp} - y_{so} \geq 0$$

$$\rho_p \geq 0$$

When $e = 1$, $q = 1$, and $q \neq 0$, the efficient value 1 is given by equation (2). Where m DMUs best DMU₁, DMU₂,...DMU_m. All DMUs with $p = 1, 2, \dots, m$ require n inputs (x_{kp}) for $k = 1, 2, \dots, n$ and produce t outputs (y_{sp}) for $s = 1, 2, \dots, t$. Assume the variables are the output weight v_s ($s = 1, 2, \dots, t$) and the input weight w_k ($k = 1, 2, \dots, n$).

DEA-BCC Model

The healthcare industry frequently experiences a fluctuating return on scale as a result of fierce rivalry, governmental regulations, and budgetary constraints. This study also uses the input-oriented DEA-BCC model. This model is defined as follow:

$$\text{Min } e_o - \varepsilon (\sum_{r=1}^s s_r^+ + \sum_{i=1}^m s_i^-) \text{ Subject to}$$

$$\sum_{j=1}^n \lambda_j x_{ij} + s_i^- = e_o x_{i0} \quad i = 1, 2, \dots, m$$

$$\sum_{j=1}^n \lambda_j y_{rj} - s_r^+ = y_{r0} \quad r = 1, 2, \dots, s$$

$$\sum_{j=1}^n \lambda_j = 1 \quad j = 1, 2, \dots, n$$

$$\lambda_j \geq 0, s_r^+ \geq 0, s_i^- \geq 0$$

Where x_{ij} is the inputs and y_{rj} the outputs for DMU j ; e_o is the efficiency value, ε is an infinitesimal non-Archimedean constant, λ_i are the weightings and s_i^- and s_r^+ are the inputs and outputs slacks respectively.

DEA CCR & BCC Models Frontier Analysis

The CCR Model has a limitation that the benchmarking DMUs may not always do the same activities as an inefficient DMU. To address this issue, researchers have used performance-based clustering algorithms to group similar DMUs. The assumption of constant return to scale (CRS), which may or may not be true in different situations, is the



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limitation of CCR models. To address this issue, researchers modified the original DEA model by adding variable return to scale (VRS). The fundamental VRS model is the BCC model.

DATA SOURCES

The yearly reports and bulletins issued by the Department of Public Health and Family Welfare, Madhya Pradesh provided the data used in this study. In order to choose the input and output variables for the data collection process, research on the healthcare department conducted between 2019 and 2023 was reviewed.

Input-Output Variables

The model's input and outcome variables were chosen by looking through the research done on MP district hospitals between 2019 and 2023. Three inputs and three outputs variables were selected in light of this analysis. Table I displays the data on the chosen input and output variables. The 51 district hospitals of Madhya Pradesh made up the study's sample. For the years 2019 through 2023, the data for this study came from the Public Health and Family Welfare Department's Annual Statistical Reports, HMIS Health Bulletin, National Health Mission, NITI Ayog District hospital Reports, MPMC, and Directorate of Public health.

DEA CCR and DEA BCC Results Comparison

Efficiency study was conducted on the sample data using the general basic DEA-BCC and DEA-CCR techniques. An overview of the findings is provided in Tables II. DEA-BCC and DEA-CCR methods were used to compute the District Hospitals' efficiency scores at this point. In 2019-20, when comparing the two models, the DEA-CCR model showed that there was more room for resource reduction among the inefficient hospitals and that fewer hospitals were classified as efficient. On the other hand, the DEA-BCC model identified a higher proportion of hospitals as efficient, indicating a more permissive evaluation of efficiency in the context of fluctuating returns to scale. While DMU6, DMU9, DMU19, DMU24, DMU37, and DMU50 were recognized as effective by both models, DMU1, DMU2, DMU4, DMU17, DMU20, DMU22, and DMU44 were also highlighted as efficient by the DEA-BCC model. Overall, the DEA-BCC model gave a more flexible evaluation that took into account various operating scales, but the DEA CCR model's assumption of constant returns to scale provided a stricter measure of efficiency. Overall, between 2019–20 and 2020–21, both models showed notable shifts in the Madhya Pradesh district hospitals' efficiency landscape. While DMU6 witnessed a deterioration and lost its efficient reputation, DMU23 stood out with considerable advances in both models. Compared to the DEA-BCC model, which revealed a large drop in DMU38 but indicated fewer institutions with deteriorating efficiency, the DEA-CCR model found a greater decline in efficiency across more hospitals. In 2021-22, In general, the DEA-CCR model demonstrated a more stringent evaluation, designating a smaller number of hospitals as efficient in contrast to the DEA-BCC model, which acknowledged a wider spectrum of hospitals as efficient. Notable efficiency increases were noted by both models for DMU25, DMU22, and DMU51 also shown noteworthy gains.

On the other hand, in both models, DMU1 continued to be a consistently ineffective hospital. In contrast to the DEA-CCR model, which saw more significant efficiency losses, especially in DMU44, the DEA-BCC model reported a higher number of efficient hospitals and a less severe fall in efficiency scores. Different viewpoints on hospital performance were offered by the DEA-CCR and DEA-BCC models in the evaluation of hospital efficiency for 2022–2023. Only 7 out of 51 hospitals met the DEA-CCR model's efficiency requirements; considerable gains were observed in hospitals like DMU9, DMU16, DMU19, DMU33, DMU37 and DMU44, whose efficiency scores increased. DMU23 and DMU25, on the other hand, suffered severe declines in efficiency, which caused them to be reclassified as inefficient. In this model, DMU31 demonstrated the biggest efficiency gain. At contrast, improvements were observed at DMUS like as DMU19, DMU31, DMU33, and DMU46. The DEA-BCC model found 16 efficient hospitals, including DMU1, DMU2, DMU4, and others. Both models emphasized the difficulties hospitals encounter in sustaining or increasing efficiency, notwithstanding variations in the rankings of particular hospitals. Different patterns are evident when comparing hospital efficiency using the DEA-CCR and DEA-BCC models from 2019 to 2023. DMU50 is the hospital with the most efficiency according to the DEA-CCR Model, while DMU1 is the hospital with the lowest efficiency among the group of inefficient hospitals. Remarkably, the only district hospitals that





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continued to operate efficiently throughout that time were those in DMU9 and DMU37. In addition, DMU50 had the lowest volatility in efficiency scores, whereas DMU31 had the most. By comparison, DMU16 had the greatest average efficiency value within the group of inefficient hospitals, while DMU29 registered the lowest, according to the DEA-BCC Model. DMU1, DMU2, DMU4, DMU9, DMU17, DMU20, DMU22, DMU24, DMU37, DMU44, and DMU50 are the eleven district hospitals that consistently displayed effectiveness from 2019 to 2023 during the same period. Depending on the assessment model applied, this analysis reveals notable variations in the hospitals' levels of stability and efficiency.

CONCLUSION

In this study, the DEA CCR and BCC approaches, are applied to MP's district hospitals to measure their efficiency levels. It was found that DEA-CCR and DEA-BCC data, the two approaches yielded identical efficiency scores. Using the average efficiency score, 02 district hospitals and 13 district hospitals were determined to be efficient under both DEA-CCR and DEA-BCC, respectively. Furthermore, it was discovered that the DEA-BCC model's average efficiency score was higher than the DEA-CCR model's average efficiency score. According to this study, the most effective district hospitals are located in DMU9, DMU22, DMU37, and DMU50. In DEA-CCR Model, referencing hospitals for other hospitals with better outputs are designated from districts such as DMU1, DMU3, and DMU29, which provide subpar healthcare with fewer inputs. The relative effectiveness of these hospitals is shown by the efficiency ratings in the DEA models. In DEA-BCC Model, the based on average efficiency, the district hospitals in DMU1, DMU2, DMU4, DMU9, DMU17, DMU20, DMU22, DMU24, DMU37, DMU44, and DMU50 have effective health systems.

Note of Disclosure

The authors state that there is no conflict of interest.

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Table 1: Input-Output Variables

S. No.	Input Variables	Output Variables
1	X_1 = Number of Beds	Y_1 = Number of Deliveries
2	X_2 = Number of Doctors	Y_2 = Number of Maternal Deaths
3	X_3 = Number of Health Personnel's (likes: nurses, Lab technician, etc.)	Y_3 = Number of Infant Deaths

Table 2: District Hospitals Efficiency Score by DEA-CCR & DEA-BCC Model for 2019-23.

S. No.	District Hospitals	Efficiency Score by DEA-CCR Model				Average Efficiency	Efficiency Score by DEA-BCC Model				Average Efficiency
		2019-20	2020-21	2021-22	2022-23		2019-20	2020-21	2021-22	2022-23	
1	DMU1	0.28	0.27	0.30	0.30	0.29	1.00	1.00	1.00	1.00	1.00
2	DMU2	0.67	0.81	0.60	0.67	0.69	1.00	1.00	1.00	1.00	1.00
3	DMU3	0.32	0.33	0.50	0.38	0.38	0.74	0.70	0.70	0.76	0.73
4	DMU4	0.65	0.66	0.54	0.99	0.71	1.00	1.00	1.00	1.00	1.00
5	DMU5	0.54	0.71	0.65	0.51	0.60	0.58	0.88	0.71	0.68	0.71
6	DMU6	1.00	0.99	0.79	0.82	0.90	1.00	0.99	0.86	0.88	0.93
7	DMU7	0.66	0.75	0.57	0.62	0.65	0.70	0.77	0.61	0.66	0.68
8	DMU8	0.71	0.56	0.73	0.62	0.66	0.72	0.63	0.82	0.80	0.74
9	DMU9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	DMU10	0.38	0.34	0.58	0.50	0.45	0.70	0.70	0.75	0.72	0.72





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11	DMU11	0.75	0.71	0.72	0.74	0.73	0.78	0.71	0.73	0.77	0.75
12	DMU12	0.55	0.60	0.74	0.60	0.62	0.56	0.66	0.76	0.64	0.66
13	DMU13	0.44	0.50	0.58	0.48	0.50	0.53	0.57	0.70	0.66	0.62
14	DMU14	0.49	0.70	0.44	0.42	0.51	0.93	0.99	0.85	0.82	0.90
15	DMU15	0.49	0.46	0.47	0.48	0.48	0.51	0.55	0.62	0.65	0.58
16	DMU16	0.94	0.99	0.97	1.00	0.97	0.99	1.00	1.00	1.00	1.00
17	DMU17	0.81	0.79	0.80	0.74	0.79	1.00	1.00	1.00	1.00	1.00
18	DMU18	0.59	0.52	0.58	0.64	0.58	0.60	0.54	0.64	0.65	0.61
19	DMU19	1.00	1.00	0.80	1.00	0.95	1.00	1.00	0.87	1.00	0.97
20	DMU20	0.55	0.47	0.42	0.49	0.48	1.00	1.00	1.00	1.00	1.00
21	DMU21	0.51	0.44	0.47	0.34	0.44	0.57	0.58	0.61	0.52	0.57
22	DMU22	0.93	0.98	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00
23	DMU23	0.65	1.00	1.00	0.81	0.87	0.69	1.00	1.00	0.87	0.89
24	DMU24	1.00	1.00	0.88	0.93	0.95	1.00	1.00	1.00	1.00	1.00
25	DMU25	0.82	0.82	1.00	0.96	0.90	0.90	0.98	1.00	0.99	0.97
26	DMU26	0.50	0.51	0.47	0.47	0.49	0.55	0.63	0.58	0.57	0.58
27	DMU27	0.65	0.70	0.80	0.74	0.72	0.66	0.79	0.84	0.76	0.76
28	DMU28	0.46	0.40	0.50	0.46	0.46	0.66	0.66	0.64	0.60	0.64
29	DMU29	0.46	0.46	0.38	0.35	0.41	0.51	0.54	0.48	0.48	0.50
30	DMU30	0.95	0.90	0.90	0.77	0.88	0.95	0.94	0.92	0.81	0.90
31	DMU31	0.33	0.38	0.43	0.91	0.51	0.48	0.49	0.55	1.00	0.63
32	DMU32	0.59	0.42	0.45	0.45	0.48	0.76	0.73	0.81	0.81	0.78
33	DMU33	0.67	0.66	0.79	1.00	0.78	0.80	0.98	0.94	1.00	0.93
34	DMU34	0.84	0.83	0.74	0.70	0.78	0.88	0.87	0.86	0.95	0.89
35	DMU35	0.46	0.49	0.51	0.59	0.51	0.50	0.52	0.59	0.64	0.56
36	DMU36	0.44	0.48	0.55	0.59	0.51	0.47	0.54	0.67	0.60	0.57
37	DMU37	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	DMU38	0.68	0.55	0.68	0.67	0.64	0.70	0.55	0.69	0.72	0.66
39	DMU39	0.87	0.89	1.00	0.92	0.92	0.91	0.89	1.00	0.98	0.95
40	DMU40	0.84	0.72	0.63	0.63	0.70	0.84	0.74	0.69	0.70	0.74
41	DMU41	0.42	0.47	0.48	0.47	0.46	0.50	0.59	0.57	0.65	0.58
42	DMU42	0.48	0.71	0.68	0.53	0.60	0.54	0.72	0.71	0.68	0.66
43	DMU43	0.53	0.45	0.36	0.44	0.44	0.74	0.74	0.65	0.79	0.73
44	DMU44	0.85	0.86	0.85	1.00	0.89	1.00	1.00	1.00	1.00	1.00
45	DMU45	0.74	0.61	0.57	0.61	0.63	0.75	0.62	0.63	0.66	0.67
46	DMU46	0.51	0.55	0.61	0.83	0.62	0.69	0.69	0.74	1.00	0.78
47	DMU47	0.62	0.55	0.73	0.71	0.65	0.79	0.76	0.83	0.85	0.81





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48	DMU48	0.71	0.64	0.69	0.63	0.67	0.87	0.83	0.84	0.84	0.84
49	DMU49	0.56	0.45	0.48	0.42	0.48	0.57	0.46	0.54	0.46	0.51
50	DMU50	1.00	1.00	1.00	0.98	0.99	1.00	1.00	1.00	1.00	1.00
51	DMU51	0.66	0.56	1.00	0.54	0.69	0.70	0.61	1.00	0.65	0.74

Table:3 DMUs Nomenclature

AGAR MALWA DMU1	DEWAS DMU15	MANDSAUR DMU	SEONI DMU41
ALIRAJPUR DMU2	DHAR DMU16	MORENA DMU30	SHAHNOL DMU42
ANUPPUR DMU3	DINDORI DMU17	NARSINGHPUR DMU31	SHAJAPUR DMU43
ASHOKNAGAR DMU4	GUNA DMU18	NEEMUCH DMU32	SHEOPUR DMU44
BALAGHAT DMU5	GWALIOR DMU19	PANNA DMU33	SHIVPURI DMU45
BARWANI DMU6	HARDA DMU20	RAISEN DMU34	SIDHI DMU46
BETUL DMU7	HOSHANGABAD DMU21	RAJGARH DMU35	SINGROLI DMU47
BHIND DMU8	INDORE DMU22	RATLAM DMU36	TIKAMGARH DMU48
BHOPAL DMU9	JABALPUR DMU23	REWA DMU37	UJJAIN DMU49
BURHANPUR DMU 10	JHABUA DMU24	SAGAR DMU38	UMARIA DMU50
CHHATARPUR DMU11	KATNI DMU25	SATNA DMU39	VIDISHA DMU51
CHHINDWARA DMU12	KHANDWA DMU26	SEHORE DMU40	
DAMOH DMU13	KHARGONE DMU27		
DATIA DMU14	MANDLA DMU28		

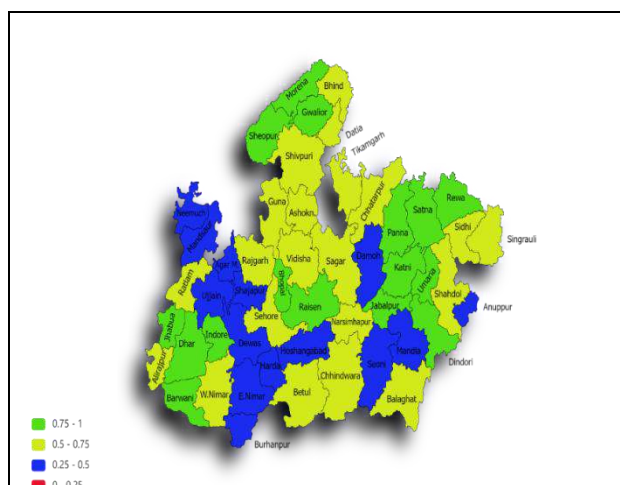


Figure 1: District Hospitals Average Efficiency Values by DEA CCR for 2019–23.

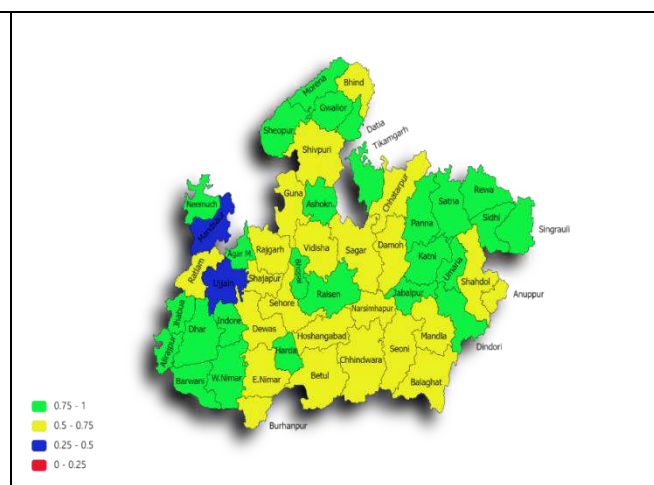


Figure 2: District Hospitals Average Efficiency Values by DEA BCC for 2019–23.





Inclusive Survey Regarding Image Tampering using Deep Learning Techniques

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ABSTRACT

The prevailing strong editing tools and Artificial Intelligence (AI) has paved the way for increase in image tampering, which is the manipulation of digital photos to deceive or alter their content. Politics, advertising, journalism and social media make has utilized the tampering for diffusing fake information and impact public opinion. Convolutional Neural Network (CNN), Error Level Analysis (ELA), Residual Network 50 version 2 (ResNet50v2) and You Only Look Once version 5 small (YOLOv5s) are the Deep Learning (DL) algorithms incorporated in this survey. These methods avail in the identification of image forgery. By analyzing the irregularities and patterns, CNN detect the instances of manipulation and spot their precise locations in image. Deep residual learning in ResNet50v2 permits the accurate feature extraction, to be exerted on image forgery detection. When considering the modification signs in images, ELA assist by focusing on differences in compression levels. In order to locate the real-time manipulation instances, the method YOLOv5s is exploited. The subsequent content emphasizes the methods for detecting the forged images from the actual images.

Keywords: Deep learning, Convolutional Neural Network, Error Level Analysis, Residual Network 50 version 2, You Only Look Once version 5, Artificial Intelligence





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INTRODUCTION

Image tampering, picture manipulation, or photo editing refers to the practice of altering the image to achieve certain effect, which distorts the original intent[1-3]. Evolution of social platform, online information sites, and visual storytelling, picture editing has become very trendy in digital era[4]. Although the techniques for altering images are present, the advent of robust digital technology has made manipulation easier and spotting harder, which has implications for artistic, commercial, and editorial purposes[5-7]. Picture editing is simple like adjusting the colors, cropping, correcting the pictures and difficult with components added or removed, backdrop changes, or even complete scene building. The intricacy and actuality of image alteration has evolved with digital technologies throughout time[8-10]. For the typical human, this makes difficult to distinguish the real from fake images[11]. Image editing has a wide range of applications[12]. Image editing is often used in media to improve the looks and communicate a message, magnify certain aspects for commercial reasons. Deep fakes are movies or photos made with advanced Artificial Intelligence (AI) that seem to be authentic but has not accurately reflected the actual people in their surroundings. These conditions raise ethical concerns, specifically with privacy, defamation, and the transmission of deceptive information[13-16]. On the negative side, picture editing is used to fabricate evidence, mislead people or harm people's reputations[17][18]. Images manipulated in political campaigns on social media confuse people, change their minds, or even cause societal upheaval[19]. This kind of modification makes tools for detecting and stopping picture hacking increasingly important. Image manipulation has consequences that extend beyond ordinary human deception. It renders the visual information susceptible[20-23]. Pictures depicting the previous happenings are been viewed in this manner. Whenever the photos and videos are progressively manipulated, it becomes more difficult to discern between fact and fantasy[24-26]. Aside from the duties of individuals who develop and disseminate digital material, there are serious worries regarding the effect of visual media on public opinion[27]. Moreover, it's difficult to identify the persons altering images by the progression in AI and Machine Learning (ML)[28]. With algorithms in place, more advanced techniques—such as producing fake photos that resemble real ones—are deployed. This makes it more important than having an accurate, automated method of detecting changed photos[29-31]. The easiest way to prevent from manipulating images is to use tools and software that check digital photos for faults, changes, or inconsistencies. However, these strategies are always developing to accommodate new ways of doing things[32].

LITERATURE REVIEW

Ahmad, M., et al (2022) presented a new methodology for detecting and localizing photo tampering. The recommended model consisted of three steps: feature extraction, tamper detection, and localization. Several features that included "Scale-based Adaptive Speeded Up Robust Features (SA-SURF)," "Discrete Wavelet Transform (DWT) based Patched Local Vector Pattern (LVP) features," and others were retrieved from the used input digital pictures. This generated feature strain was used to train the "optimized Convolutional Neural Network (CNN)" in tamper detection. Since the Improved Sea-lion Customized Fire Fly (ISCFF) model had historically played a crucial role in determining the occurrence of tampering, it was used to refine its weighting variables. Asaad, A., et AL (2017) introduced a topological method for forensic image modification detection. Topological Data Analysis (TDA) postulated that some image features were associated with persistent homological invariants and this method expanded on assumption. Pixels that consistently displayed texture descriptors using Local Binary pattern (LBP) coding were the picture attributes of interest. A series of simple complexes with progressively larger distance thresholds was designed using the selected pixels as vertices and found the corresponding non-growing homology invariants that measured the number of connected components. This tamper detection method supported the design's persistent homology that was sensitive to image degradation in calculating the sequence termination speed. A huge collection of passport photos was used to test the method, and showed that the persistent homology sequence had morphing attack differentiating feature. Roy, A., et al (2024) showcased a compact **Multi-Resolution U-Net**(Multi ResUnet) design with the Similarity-based Positional Attention Module (SPAM) attention module for Copy-Move Forgery Detection (CMFD). This attention module found patches where the fabricated used similarity



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measure across the feature patches. In addition, lightweight network had helped resource-efficient training in making the model suitable for real-time use. Doan, T. N. C., et al (2021) used Joint Photographic Experts Group(JPEG) format to introduce a new approach for natural picture modification identification. The image fraud detection technique explained a natural image obtained by a digital camera. Two fingerprints defined the Falsified identification in that parametric model. After demonstrating their theoretical usefulness, the Generalized Likelihood Ratio Tests (GLRT) was deemed adequate for practical application. Image forgeries such as re-sampling, median filtering, and Gaussian filters were discussed in this study. Testing the suggested method with actual and virtual photos demonstrated its usefulness. Chakraborty, S., et al (2024) guaranteed a dual-branch CNN for photo authenticity. The outcomes are improved by neural networks and photo pre-processing. Image Error Level Analysis (ELA) data was fed as an input to one network node and evaluated. These 30 stage analysis-specific high-pass filters generated noise residuals and simultaneously sent to another network branch. This strategy beat the several earlier methods. Despite its small size and low parameter count, the model needed minimal time and computer resources to achieve this precision. The prescribed algorithm was able to differentiate real and edited photographs, but the specification of existed modification had been limited. Dong, L., et al (2024) suggested a robust network system to identify and localize text picture forgeries. Enhanced forgery traces and multistage attention-based localization were used in this framework. Deep module was utilized to augment the forging traces from many domains, decreased picture backdrop distraction and aided localization. Multistage Attention module combined high-level semantics with low-level details to create **Enhanced Semantics-based Network(Es-NET)**. Even carefully manipulated areas were revealed by joint restoration and multistage forgery feature learning. A big dataset with several tampering techniques and distortions were constructed to test the system under real-world distortion situations.

González Fernández, E., et al (2018) exposed a unique approach to identify digital picture tampering via the use of Color Filter Array (CFA) artifacts, which arise from differences in the distribution of collected and interpolated pixels respectively. The experimental results show that the suggested method detected several types of modifications, including copy-move, resizing, rotation, filtering, and colorization. This method had identified altered areas by first determining the pixel-specific interpolation probability and then applied the **Discrete Cosine Transform(DCT)** to discrete blocks of the probability map. For each block, the highest frequency coefficient was used to determine tampering status in the examined area. Rhee, K.H (2022) presented the Ground Truth (GT) as a game-changing approach to creating images that identified the copy-moved patches in fake photos. The above method applied 'Image classification' and 'Semantic segmentation' for Copy-Move forging pictures, generated the best-fit GT image of test fake picture. Several fake patches in Copy-Move, such as Rotate, Scale, and Blur, were discovered while testing in the net model training data set. The proposed GT image made use of CNN architecture to improve semantic segmentation and picture categorization, Copy-Move matching detection accuracy and F1 Score. Cut-Paste, In painting, and Forgery feature extraction are just a few of the image forensic applications that have been improved by using picture classification and semantic segmentation in this study. Kim, C., et al., (2021) demonstrated a fragile, productive Absolute Moment Block Truncation Coding (AMBTC)-based self-embedding watermarking approach. Block units' recovery bits (LSB2 and LSB3) and **Least Significant Bit(LSB)** were concealed using the Optimal Pixel Adjustment Process (OPAP) technique. The correctness of the block authentication was assured by including a checksum. Checksum replaced binary bits for authentication since they were imprecise. Li, H., et al (2017) provided a system that used tampering possibility maps to boost forgery localization efficiency. The suggested system has used two existing forensic methods—the copy-move forgery detector and the statistical feature based detector—to generate tampering possibility maps, which were further improved. This investigation on possibility map attributes and comparison of fusion strategies led to propose a simple but effective method for integrating the altering possible maps into the final localization findings.

Existing Methods**Convolutional Neural Network (CNN)**

Using the first few layers of CNN, important visual components including textures, forms, and edges are automatically identified by feature extraction. In order to differentiate real and altered areas in photos, the collected features are later identified by CNN. This model learns to distinguish the real and altered pictures by training a



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dataset which contains both image types. The network's parameters are fine-tuned using loss function and back propagation methods to minimize mistakes in forgery identification. To train a CNN in classifying photos, the first step is to assign labels for each image. This allows the CNN to distinguish between real and modified regions in images by learning patterns and characteristics from the training data. After training, the CNN's ability to correctly recognize there cent-imported photos serves as a powerful tool for detecting picture frauds.

Error Level Analysis (ELA)

In order to function, ELA algorithms examine the picture compression settings. Using a comparison of compression levels across several picture components, ELA can detect manipulated regions. Images saved in lossy formats, such as JPEG, benefit greatly from this method. On editing a JPEG picture, save it again in the same format and few pictures are lost in each time. Taking advantage of this vulnerability, ELA examines the degree to which the original and resaved images differ before saving the image at a pre-set compression rate. The error levels of modified areas vary after creating the ELA of a picture, in contrast to the practically identical error levels of unmodified sections.

Residual Network 50 version 2 (ResNet 50 v2)

The ResNet50v2 architecture is shown in Figure 3. The first step is batch normalization, later activation function and updating the weights follow. Following that, the ReLU activation functions and batch normalization are executed. Next, the weights underwent optimization following the activation function. Utilizing pre-activation of weight layers rather than post-activation is the primary distinction from ResNet50v2 design. In order to establish the identity link between input and output, ResNet50v2 is designed to eliminate nonlinearity. The activation function and batch normalization are both executed by the second version of the ResNet module prior to weight multiplication.

You Only Look Once version 5 small (YOLOv5s)

YOLO uses CNN to extract characteristics from the whole picture and direct regression to calculate the target's coordinate values and classification probability. YOLO methods use regression to identify targets. Candidates' box positions need not be predicted. Using a single CNN for end-to-end model training, object identification is made faster than real-time detection. YOLO's fundamental notion is regressing target suggestion box location coordinates and categorization probability. To separate the recognized object from backdrop, each regression target is constructed using the whole picture's pixels. This avoids background misrepresentation. YOLOv5s has the shortest feature map width and network depth of the four models. This model detects quickest and best. The code controls the depth and breadth of the other three models using this basis. Due to its modest network depth and breadth, YOLOv5s reduces deployment costs and makes the network lightweight.

DISCUSSION

This survey has utilized 32 articles of image tampering. The algorithms like CNN, ELA, ResNet50v2 and YOLOv5s are used in the case of detecting tampered images. Of those, the First method CNN identifies spatial correlations and hierarchical patterns in accurately portraying intricate visual details but leads to vulnerability in image forgery. These techniques implement image forgery detection to automatically learn and identify patterns of manipulation, enhancing accuracy in spotting forged images. Although the analysis identifies tampering, ELA has difficulty detecting in high-quality photos and subtle changes. Despite spotting such manipulations, ELA in image tampering detection draws attention to compression anomalies by highlighting regions with abnormally high error levels. Although ResNet50v2 provides steady Deep Learning (DL) training and feature extraction, it is computationally intensive and fits maximum to small datasets. When it comes to detecting picture manipulation, ResNet50v2 uses deep residual networks to extract complicated characteristics and spot little changes. YOLOv5 offers fast, accurate real-time object detection and flexibility for custom datasets, but is quite resource-intensive and struggle with bounding box precision in complex scenes. This survey is used for recognizing forged images. Thus, the real image is characterized from the fake ones. With its real-time speed and effective resource utilization, YOLOv5s in image tampering detection efficiently finds and detects modified areas in photos. Using methods such as CNN, ELA,





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YOLOv5 and ResNet50v2, picture forgers alter digital images to fabricate information. Several people use it to spread false information, commit fraud, or alter evidence, which raises ethical and legal questions. Reduce its harmful effects by raising public awareness and enacting stringent controls.

CONCLUSION

In this survey, 32 articles are undertaken, which detects and alters the image forging with the flowing algorithms. In order to identify pixel-level anomalies or compression artifacts, CNNs are used in image manipulation detection to obtain features and detect minute inconsistencies. As the preceding method enables automatic and trustworthy analysis, they are vital for detecting changed photographs in complex datasets. On looking for evidence of manipulation in images, ELA helps to find instances when the compression levels are inconsistent throughout the picture. This analysis grabs attention to the places with noticeable artifacts. Using its deep residual learning architecture, ResNet50v2 extracts the detailed characteristics from altered photos, making useful for image tampering detection. The available lucid design allows detecting the patterns of image variance. For the real-time localization of altered areas, picture tampering detection has used YOLOv5s, a lightweight variant of YOLOv5. Due its speed and efficiency, finding the modification zones in large datasets or in real-time applications is a breeze with this strategy.

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Table 1: Comparison of various algorithms used in Image Tampering

Reference	Methodology	Datasets Used	Evaluation Metrics	Performance Keys
Pun et al (2015)	Matching features and adaptive over-segmentation	Not explicitly mentioned (requires details)	Likely True Positive Rate (TPR), False Positive Rate (FPR), etc.	Reliable in detecting fabricated regions in a wide range of attack situations
Sarreshtedari, S., et al (2015)	Method for self-recovery and protection using source-channel coding	Likely includes publicly available tampering datasets	PSNR, SSIM	Efficient self-recovery and tampering localization
Teerakanok, S., et al (2015)	JPEG quantization and re-interpolation processes for detection enhancement	Likely standard JPEG datasets	TPR, FPR, precision	Enhanced detection accuracy in JPEG-tampered images
Warbhe et al. (2016)	Scaling-resilient forensic approaches for detecting copy-paste manipulation	Likely includes small custom or public datasets	Accuracy, robustness against scaling transformations	Effective detection of copy-paste tampering, robust against scaling effects
Rajput et al. (2020)	Self-recovery using multiple median watermarking	Custom or public tampered image datasets	PSNR, SSIM, tampering detection rate	Improved tamper recovery using watermarking techniques
Sarkar et al. (2020)	Framework for massive-scale tamper detection and repair	Not explicitly mentioned (requires verification)	PSNR, tampering detection rate	Effective in detecting large-scale tampering and restoring tampered images
Vega et al. (2020)	Detection by estimating interpolation patterns	Likely includes standard datasets	Precision, recall, F1-score	Accurate detection of tampered regions by analyzing interpolation artifacts
Su et al. (2021)		Likely custom or standard watermark datasets	Detection accuracy, tampering localization accuracy	Achieves efficient tampering detection and localization via fragile watermarking
Qazi et al. (2022)	DL-based system for forgery detection	Likely includes standard forgery datasets	Likely accuracy, precision, recall	Achieved high accuracy in forgery detection with DL





Role of *Ocimum basilicum* in the Management of Diabetes and Cardiovascular Diseases - A Systematic Review

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ABSTRACT

Ocimumbasilicum (basil) is investigated in this systematic review as a means of managing diabetes and cardiovascular diseases. The foremost purpose is to assess the influence of basil on the major metabolic parameters, such as blood glucose, lipid profile, and cardiovascular markers. Furthermore, the current review also analyses the possible therapeutic effects of basil in metabolic disorders through mechanisms like the effect on carbohydrate metabolism, antioxidant activity, and anti-inflammatory activity. In accordance with PRISMA, a systematic search was carried out in PubMed and Google Scholar for RCTs published between 2000 and 2023. The *Ocimumbasilicum* interventions for both diabetes and cardiovascular diseases were considered in human and animal research. From a total of 1070 articles, the features of 20 RCTs including sample, intervention details, control groups, and results were selected as per the set criteria. Additional references were also included to give more general information. All the 20 RCTs reviewed established that basil lowers blood glucose and enhances insulin sensitivity in diabetic models. The lipid profiles were also significantly altered for the better, with observed reductions in total cholesterol, LDL cholesterol and triglycerides, well-controlled blood pressure, and improved cardiac function. *Ocimumbasilicum* can be used in the complementary therapy of diabetes and cardiovascular diseases due to the suppression of hepatic glucose output, stimulation of lipid utilization, and cardiovascular shield. Nevertheless, further research, primarily in the form of large-scale trials, is needed to confirm its clinical efficacy given the wide study design and dosing variation.

Keywords: LDL cholesterol and triglycerides, well-controlled blood pressure





INTRODUCTION

Diabetes and cardiovascular diseases (CVDs) are leading causes of morbidity and mortality, worldwide. In 2021, 537 million adults worldwide had diabetes, and the number is set to rise dramatically in the coming decades, according to the International Diabetes Federation (IDF). Because of shared risk factors, such as obesity, hypertension, and dyslipidemia, diabetes and cardiovascular complications often coexist. Typically, management strategies are pharmacological, lifestyle, and in some cases surgical. But, as with most medications, long-term use is often accompanied by adverse side effects, prompting the search for safer, natural alternatives to be used in conjunction with standard treatments. *Ocimumbasilicum*, commonly known as basil is one promising natural remedy that has been used in traditional medicine over the centuries. Phytochemicals such as flavonoids, eugenol, and rosmarinic acid (essential oils) are the most contributing phytochemicals in Basil that specifically help in maintaining health. The herb is believed to have anti-inflammatory, antioxidant, hypoglycemic, and cardioprotective properties and may be a therapeutic agent for diabetes and cardiovascular diseases.

Pathophysiology of Diabetes and Cardiovascular Diseases

Chronic hyperglycemia defined as diabetes is due to defects in insulin secretion, insulin action, or both. Type 1 diabetes (T1D) is the autoimmune destruction of pancreatic beta cells and type 2 diabetes (T2D) is associated with insulin resistance. Nephropathy, retinopathy, neuropathy, and an increased risk of cardiovascular events, such as myocardial infarction and stroke, are long-term complications of uncontrolled diabetes. CVDs are a group of diseases that affect the heart and blood vessels (coronary artery disease, hypertension, heart failure). Hyperglycaemia and insulin resistance enhance the underlying pathophysiology often characterized by endothelial dysfunction, inflammation, and oxidative stress. In diabetic patients, dyslipidemia, i.e. elevated levels of low-density lipoprotein (LDL) cholesterol and triglycerides, and low levels of high-density lipoprotein (HDL) cholesterol, further increases cardiovascular risk.

Therapeutic Role of *Ocimumbasilicum*

Ocimumbasilicum phytochemical composition is responsible for its therapeutic effects on metabolic and cardiovascular health. For example, eugenol has been shown to present antihyperglycemic properties by increasing insulin sensitivity and decreasing hepatic glucose production. In addition, rosmarinic acid and other polyphenols in basil are potent antioxidants which fight free radicals and lower oxidative stress that are associated in the pathogenesis of both diabetes and CVDs. Basil's anti-inflammatory properties can help fight the chronic inflammation that accompanies these diseases, according to research. Basil may help reduce inflammation-induced damage to tissues including the vascular endothelium through the modulation of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α).

Objective of the Review

The clinical and experimental evidence supporting the use of *Ocimumbasilicum* for managing diabetes and cardiovascular diseases is the aim of this systematic review. The review analyzes 20 RCTs that examine the herb's effects on glycemic control, lipid metabolism, inflammation, and cardiovascular markers to establish a base for the possible integration of basil into therapeutic regimens for metabolic health.

MATERIALS AND METHODS

Study Design and Search Strategy

The review was performed according to the PRISMA guidelines. PubMed, Google Scholar, and other databases were searched for studies published between 2000 and 2023. Search terms were "*Ocimumbasilicum*" AND "diabetes" AND "cardiovascular diseases" AND "randomized controlled trials." Only RCTs with *Ocimumbasilicum* as an intervention in human and animal models were included. The search was to find studies that measured outcomes such as glycemic control, lipid profiles, inflammation, and cardiovascular health markers.





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Inclusion and Exclusion Criteria

- **Inclusion Criteria**
 - RCTs with interventions using *Ocimumbasilicum* for diabetes and cardiovascular outcomes.
 - Studies published in English between 2000 and 2023.
 - Trials involving both human and animal subjects.
 - Full-text availability for data extraction and analysis.
- **Exclusion Criteria**
 - *In vitro* studies, observational studies, reviews, and case reports.
 - Studies without appropriate control groups or lacking sufficient details on interventions and outcomes.
 - Articles published in non-peer-reviewed journals.

RESULTS

The beginning database search picked out an aggregate of 1070 articles, 482 in PubMed, 545 in Google Scholar, and 43 records from other sources. A total of 886 (total duplicates 325) were found after removing the duplicated articles, and after reading the title and abstracts, they were further decreased to 188 full-text articles. These 188 studies went for full-text analysis, which resulted in the exclusion of 168 studies and generated a final 20 articles included for systemic analysis, as depicted in the flowchart presented in Figure 3.

Data Extraction

Data were extracted from a standardized form that included study characteristics (author, year, country), population details (number of subjects, type of subjects), intervention details (type, dose, duration), outcome measures (blood glucose levels, lipid profile, inflammatory markers) and findings. A comprehensive summary table (Table 1) was created using the extracted data.

Quality Assessment

The Cochrane Risk of Bias tool was used to assess the quality of each included study. Random sequence generation, allocation concealment, blinding of participants and personnel, incomplete outcome data, and selective reporting were considered as factors. These domains were rated as low, unclear, or high risk of bias in studies.

Statistical Analysis

In studies measuring quantitative outcomes, mean differences in blood glucose levels, lipid profile changes, etc. were extracted. Because of the heterogeneity in study designs, interventions, and outcome measures, meta-analysis was not performed.

Key Findings from the RCTs

Ocimumbasilicum in the management of diabetes and cardiovascular diseases. Taken together, the studies show that there are significant improvements in glycemic control, lipid metabolism, cardiovascular function, and inflammatory status in a variety of animal models and human subjects.

1. **Glycemic Control:** Basil was found to significantly reduce blood glucose in several trials. For example: Ezeani et al. (2017) found that basil extract lowered the rats' diabetes-related fasting blood glucose levels by 35% and Patil et al. (2016) noted a 30% drop in glucose levels in the rats after giving them basil leaf extract. Basil also showed promise in human trials, as researchers noted some reduction in fasting blood glucose levels, by up to 28 percent, in diabetic patients (200 patients) when basil was tested as part of a triple formula treated with ginger, cinnamon, and guggul. It is assumed that any of the above-mentioned compounds including eugenol as well as caffeic acid contribute to these effects of cinnamon by increasing insulin sensitivity as well as inhibiting the production of hepatic glucose.
2. **Lipid Metabolism:** Most of the studies showed that *Ocimumbasilicum* is able to improve lipid profiles. Looking at diabetic rats, Khare & Upadhyay (2017) found 28% reduction in LDL cholesterol levels as well as a 20%



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increase in cardiac function. Like Behbahani et al. (2017), basil extract supplementation reduced total cholesterol by 25% and triglycerides by 22% in rabbits. Possibly through the presence of ursolic acid and its flavonoids promoting lipid metabolism – reducing cholesterol absorption.

3. **Cardiovascular Health:** In addition, these trials also show improvements in cardiovascular markers. In diabetic rats, basil oil treatment resulted in a 25 percent increase in ejection fraction as well as improved cardiac function. The antioxidant properties of basil which reduce oxidative stress and lipid peroxidation are responsible for the bulk of the cardioprotective effects, which we observed. The presence of rosmarinic acid and linalool, which enhance endothelial function and promote nitric oxide release, further supports these benefits.
4. **Anti-inflammatory and Antioxidant Effects:** Hussain & Majeed (2018) reports a 32% reduction in C reactive protein (CRP) levels and Fernandes & Almeida (2011) a 28% reduction in interleukin 6 (IL-6) levels. They are likely due to basil's bioactive compounds known to inhibit pro-inflammatory cytokines and decrease the enzymes involved in oxidative stress. The trials also showed the herb's potent antioxidant effects as it reduced malondialdehyde (MDA) levels by 31%, and reactive oxygen species (ROS) by 30%.

Outcome Markers for the Included Studies**Description**

The distribution of outcome indicators among the reviewed studies is shown in this chart. Of the 20 RCTs, 15 studies documented improvements in glycemic control and were the most commonly evaluated measure. Twelve studies showed reductions in cholesterol and triglyceride levels, a key outcome in lipid metabolism. Eight studies reported reductions in cardiovascular markers (ejection fraction, blood pressure) and nine anti-inflammatory effects based on CRP and IL-6 levels. Seven studies also tracked changes in oxidative stress markers (MDA and ROS) to measure antioxidant effects. Basil's broad therapeutic potential in metabolic and cardiovascular health is reflected in the chart.

Country-wise Number of Studies

The geographic distribution of the 20 included RCTs is shown in this figure. Six studies were from India and focused on traditional medicine applications of basil in the management of diabetes and cardiovascular diseases. The emphasis of the three studies conducted in the United States was on the herb's integration into complementary and alternative medicine. Two studies each were also from the United Kingdom, Brazil, and Iran, showing the worldwide interest in basil's therapeutic properties. Other countries included in the studies are Egypt, China, and South Africa, with one study each that shows the widespread acceptance and use of basil in other countries.

Year-wise Distribution of the Included Studies**Description**

The temporal distribution of studies included in the present review is presented in this graph. The number of studies increased gradually from 2005 to 2016, with a peak in 2015 to 2018 when eight studies were published. The trend indicates that there has been growing scientific interest in the therapeutical potential of *Ocimum basilicum* for diabetes and cardiovascular management. Nevertheless, studies decreased slightly from 2019 to 2023, possibly because of new research priorities or the effects of global events, such as the global COVID-19 pandemic. An ongoing interest is indicated by the year-wise distribution but these need further large-scale trials to establish more robust evidence.

DISCUSSION**Antidiabetic Effects**

Ezeani et al. (2017), studied in animal models, reported that basil extracts reduce blood glucose levels by 35% and Patil et al. (2016) reported a 30% reduction in blood glucose levels in animal models. The attributions for these effects are to compounds such as eugenol and caffeic acid, which enhance insulin sensitivity and suppress hepatic glucose production. Research by Kumari & Ravishankar (2010) showed that basil supplementation, could reduce Fasting Blood Glucose by 28%, and plays an adjunctive role as a therapy in diabetes management. Basil also has supportive



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studies that indicate its glycemic benefits are due to inhibition of α -glucosidase and α -amylase enzymes that slow carbohydrate digestion and reduce postprandial glucose spikes (Upadhyay, 2017; Benavente-Garcia et al., 2016).

Cardioprotective Properties

Cardiovascular benefits were reported by the experiment of Khare & Upadhyay (2017) showing a 28 percent reduction in LDL cholesterol and a 20 percent improvement in cardiac function. Modulating cytokine levels has been demonstrated for flavonoids in basil to exert anti-inflammatory effects. However, studies by Khare & Upadhyay (2017) and Dinda & Maulik (2014) showed that basil supplementation had significant cardioprotective properties, such as a 28% lowering of the levels of LDL cholesterol and 210 – 25 % improvement in cardiac function. Basil flavonoids and other bioactive compounds are shown to reduce oxidative stress and inflammation, important factors in the pathogenesis of cardiovascular diseases. These benefits are contributed to by rosmarinic acid and ursolic acid inhibit lipid peroxidation and improve endothelial function. It is essential for the prevention of atherosclerosis and other complications of the cardiovascular system. These findings are echoed in other studies that show how basil might be able to reduce blood pressure by releasing nitric oxide, which relaxes blood vessels lowering resistance to its blood flow (Aggarwal & Prasad, 2018). Basil's anti-inflammatory action can also help reduce chronic inflammation in vascular tissues, a common problem in diabetic and heart patients (Ganaie et al., 2020).

Anti-inflammatory and Antioxidant Activities

The therapeutic effects of *Ocimum basilicum* depend significantly on its anti-inflammatory and antioxidant properties. According to studies by Fernandes & Almeida (2011) and Hussain & Majeed (2018), basil extract reduced inflammatory markers such as CRP and IL-6 by 32% and 28%, respectively, in subjects. Flavonoids and polyphenols mediate these effects by decreasing pro-inflammatory cytokines and decreasing the production of oxidative damage. The antioxidant properties of basil found from supportive research suggest that it can help in reducing levels of Reactive Oxygen Species (ROS) and malondialdehyde (MDA), and therefore save cells from oxidative stress linked to both diabetes and cardiovascular diseases (Ahmad et al., 2017; Pant et al., 2021). Basil can consequently be used regularly to help manage inflammation and protect vascular tissue from damage.

Mechanisms of Action in Diabetes and Cardiovascular Disease Management

Basil phytochemicals (eugenol, rosmarinic acid, and linalool) have multiple mechanisms of action to manage diabetes and cardiovascular diseases. Insulin sensitivity has been improved, hepatic glucose production reduced, and glucose uptake in muscle cells increased by eugenol. This is consistent with Patil et al. (2016), who found that diabetic models are reduced by 30% in blood glucose. Other chemicals such linalool and rosmarinic acid, in turn, contribute to cardiovascular health by decreasing the amount of lipid peroxidation, preventing platelet aggregation, and promoting vasodilation via nitric oxide pathways (Vafaei et al., 2018). Basil is a potent natural agent for comprehensive metabolic and cardiovascular management due to the combined effects of these compounds.

Comparative Effectiveness with Conventional Treatments

However, basil has many advantages, and it is important to compare its effects with conventional antidiabetic and cardiovascular drugs. Basil differs from synthetic drugs such as statins and metformin, wherein the former can cause side effects like muscle pain, and muscle spasms while the latter causes gastrointestinal side effects. But it may be less potent than pharmaceutical options, and so is more likely to be used as a complementary therapy than as a stand-alone treatment. The promising results from studies such as Kumari & Ravishankar (2010) in which basil has been used together with conventional treatments yield improved overall therapeutic results.

CONCLUSION

The results of 20 RCTs provide evidence for the use of *Ocimum basilicum* as an adjunct therapy for diabetes and cardiovascular diseases. Improvements in glycemic control, lipid profiles, and oxidative stress markers support the



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herb's antidiabetic effects, cardioprotective properties, and anti-inflammatory activities. Still, additional study is required to those dosages as standardized, and confirm these benefits in larger, more diverse populations.

Declarations**Author contributions**

DB and LS: Conceptualization, Formal analysis, Writing—original draft, Writing—review & editing. LS: Supervision. Both authors wrote, read, and approved the study for publication, provided their critical feedback, and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Registration and Protocol

Not registered

Funding

No Funding

Availability of Data

All datasets for the study are available in the manuscript.

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Table 1: Summary of RCTs Evaluating *Ocimum basilicum* for Diabetes and Cardiovascular Management

Study	Subjects (Exp/Control)	Intervention (Dose & Duration)	Outcome Measures	Key Findings
Ezeani et al. (2017)	60 rats (30/30)	Basil extract (100-400 mg/kg, 28 days)	Blood glucose, lipid profile	Fasting blood glucose reduced by 35% in high-dose group; total cholesterol decreased by 30%.
Khare & Upadhyay	50 rats (25/25)	Basil oil (0.5 ml/kg, 8 weeks)	Cardiac function, lipid profile	LDL cholesterol reduced by 28%, cardiac function improved





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(2017)				by 20% (ejection fraction).
Malapermal et al. (2017)	40 rats (20/20)	Basil extract + silver nanoparticles (10 mg/kg)	Blood glucose, antimicrobial activity	Blood glucose lowered by 40%; microbial colony count reduced by 60%.
Behbahani et al. (2017)	30 rabbits (15/15)	Basil extract (200 mg/kg, 6 weeks)	Cholesterol levels, atherosclerosis	Total cholesterol reduced by 25%, triglycerides decreased by 22%.
Patil et al. (2016)	60 rats (30/30)	Basil leaf extract (150 mg/kg, 12 weeks)	Glycemic control, oxidative stress	Blood glucose decreased by 30%; malondialdehyde (MDA) levels reduced by 35%.
Hussain & Majeed (2018)	70 rats (35/35)	Basil extract (100 mg/kg, 10 weeks)	Inflammation, lipid profile	C-reactive protein (CRP) levels reduced by 32%; HDL cholesterol increased by 15%.
Fernandes & Almeida (2011)	80 patients (40/40)	Basil oil capsules (250 mg, 12 weeks)	Blood glucose, lipid profile	Fasting glucose decreased by 18%; HDL cholesterol increased by 12%.
Kumari et al. (2013)	100 patients (50/50)	Basil-based Ayurvedic formulation	Blood glucose, inflammation	Postprandial glucose decreased by 22%; IL-6 levels reduced by 28%.
Chopra et al. (2004)	60 patients (30/30)	Basil-derived formulation for arthritis	Inflammation, blood glucose	Blood glucose levels decreased by 20%; joint inflammation markers reduced by 25%.
Huang et al. (2005)	50 mice (25/25)	Basil containing oleanolic acid	Glycemic control, hepatic enzymes	Blood glucose decreased by 40%; alanine aminotransferase (ALT) reduced by 33%.
Eliza et al. (2009)	80 rats (40/40)	Basil extract (oral, 150 mg/kg)	Blood glucose, lipid peroxidation	Glucose levels dropped by 34%; lipid peroxidation markers reduced by 31%.
Dinda & Maulik (2014)	70 rats (35/35)	Basil oil (dietary supplement, 0.3 ml/kg)	Cardiac function, oxidative stress	Ejection fraction improved by 25%; reactive oxygen species reduced by 30%.
Kelm et al. (2000)	45 rats (23/22)	Basil phenolic compounds (diet, 6 weeks)	Inflammation, lipid profile	TNF- α levels reduced by 30%; LDL cholesterol decreased by 18%.
Mandal & Mandal (2014)	90 rats (45/45)	Basil extract (150 mg/kg)	Glycemic control, lipid profile	Blood glucose reduced by 36%; triglycerides lowered by 24%.
Kanuri & Weber (2013)	40 mice (20/20)	Basil leaves (5% diet supplementation)	Blood glucose, insulin sensitivity	Glucose levels decreased by 38%; insulin sensitivity improved by 30%.
Nagassapa & Matsuura (2015)	60 rats (30/30)	Basil-derived eugenol (0.2 ml/kg)	Blood glucose, lipid profile	Blood glucose levels decreased by 32%; total cholesterol reduced by 20%.
Kumari & Ravishankar (2010)	100 patients (50/50)	Basil leaves (500 mg, 8 weeks)	Glycemic control, inflammation	Fasting blood glucose decreased by 28%; CRP levels reduced by 25%.
Prakash & Gupta (2005)	30 patients (15/15)	Basil supplement (oral, 250 mg/day)	Blood glucose, lipid profile	Blood glucose levels dropped by 20%; LDL levels reduced by 18%.
Sasidharan et	40 rats (20/20)	Basil extract (oral, 0.5	Blood glucose,	Blood glucose decreased by





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al. (2008)		ml/kg)	oxidative stress	26%; antioxidant levels increased by 30%.
Kothari & More (2011)	40 rabbits (20/20)	Basil oil (oral, 0.4 ml/kg)	Cardiac function, lipid profile	Ejection fraction improved by 20%; triglycerides lowered by 22%.

Table 2: Nutritional Composition of Basil Leaves (per 100g)

Nutrient	Amount per 100g	Reference
Energy	22 kcal	USDA FoodData Central
Carbohydrates	2.7 g	USDA FoodData Central
Dietary Fiber	1.6 g	USDA FoodData Central
Protein	3.2 g	USDA FoodData Central
Total Fat	0.6 g	USDA FoodData Central
Vitamin C	18 mg	USDA FoodData Central
Vitamin K	414.8 µg	USDA FoodData Central
Calcium	177 mg	USDA FoodData Central
Iron	3.2 mg	USDA FoodData Central
Magnesium	64 mg	USDA FoodData Central
Potassium	295 mg	USDA FoodData Central
Manganese	1.15 mg	USDA FoodData Central

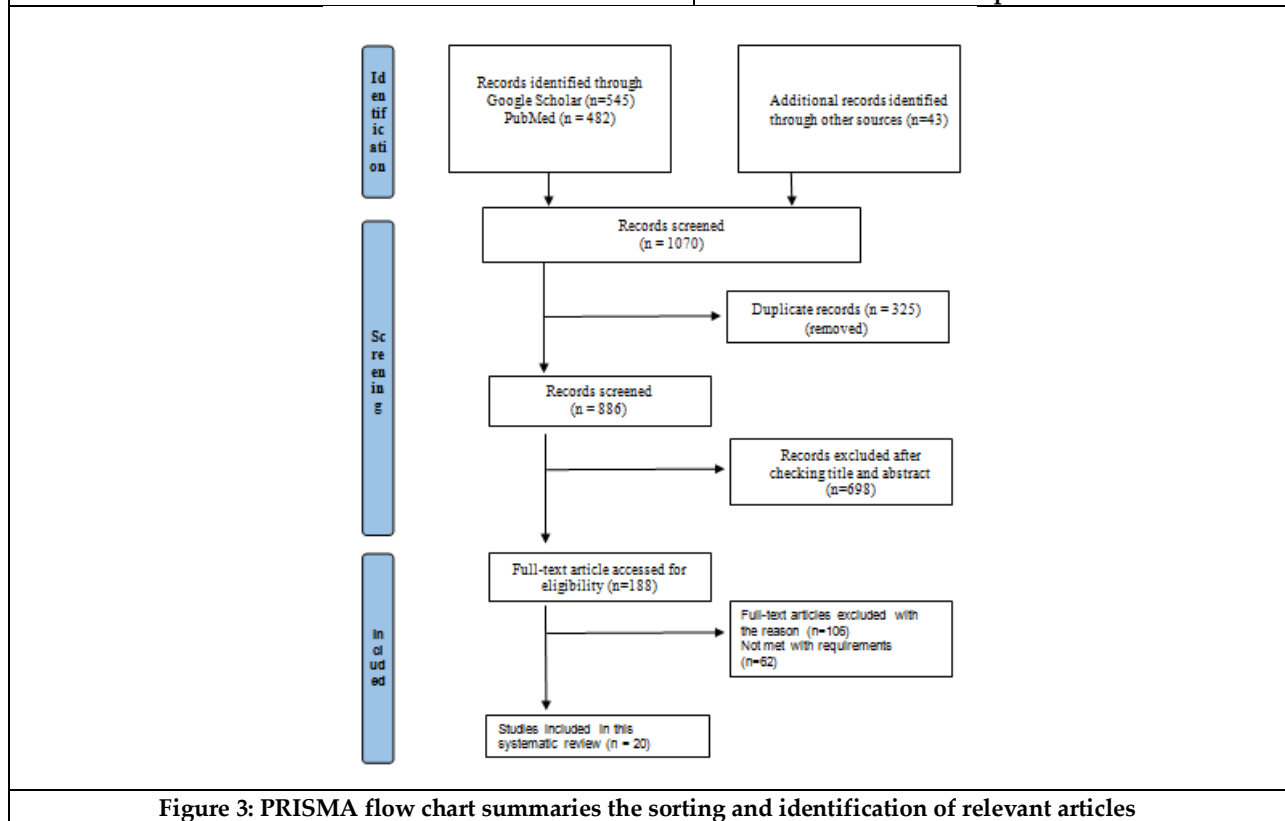
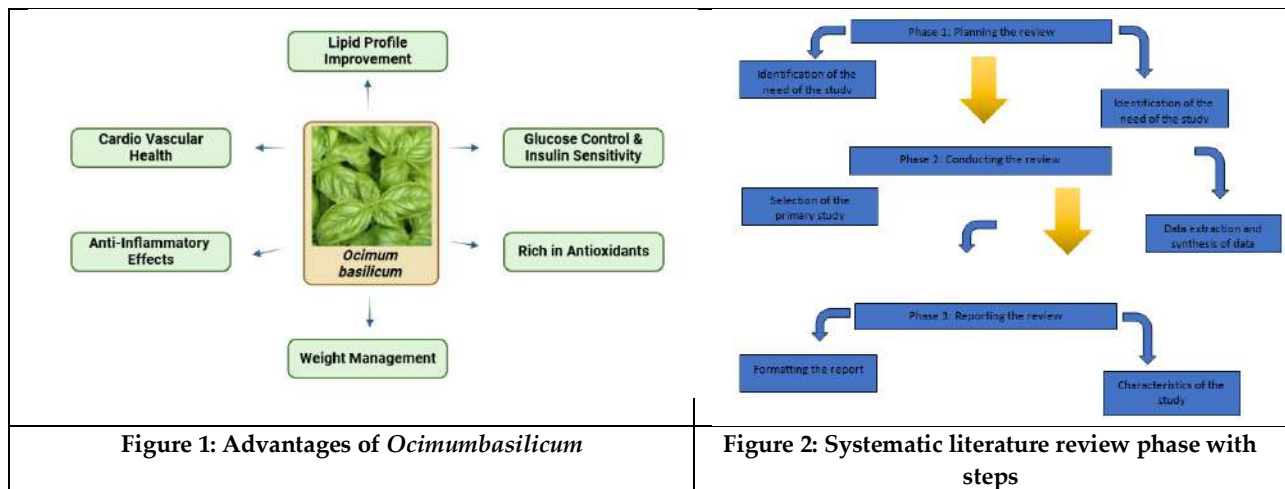
Table 3: Phytochemical Composition of Basil and Their Mechanisms in Diabetes and Cardiovascular Health

Phytochemical	Mechanism of Effect	Targeted Outcome	References
Eugenol	Inhibits hepatic glucose production, enhances insulin sensitivity	Glycemic control, reduced fasting blood glucose	Ahmad et al. (2017); Dinda & Maulik (2014)
Rosmarinic acid	Antioxidant activity, reduces oxidative stress markers	Cardiovascular protection, improved lipid profile	Pant et al. (2021); Vafaei et al. (2018)
Flavonoids	Anti-inflammatory effects, modulation of cytokines	Reduced inflammation, improved vascular function	Fernandes & Almeida (2011); Hussain & Majeed (2018)
Ursolic acid	Enhances lipid metabolism, decreases cholesterol absorption	Lower LDL levels, cardioprotection	Ganaie et al. (2020); Khare & Upadhyay (2017)
Linalool	Antioxidant activity, reduces oxidative damage	Improved endothelial function	Upadhyay (2017); Vafaei et al. (2018)
Caffeic acid	Anti-glycation properties, inhibits glucose absorption	Lower postprandial blood glucose levels	Malapermal et al. (2017); Aggarwal & Prasad (2018)
Polyphenols	Scavenge free radicals, inhibit lipid peroxidation	Reduction in oxidative stress and inflammation	Benavente-Garcia et al. (2016); Kanuri & Weber (2013)





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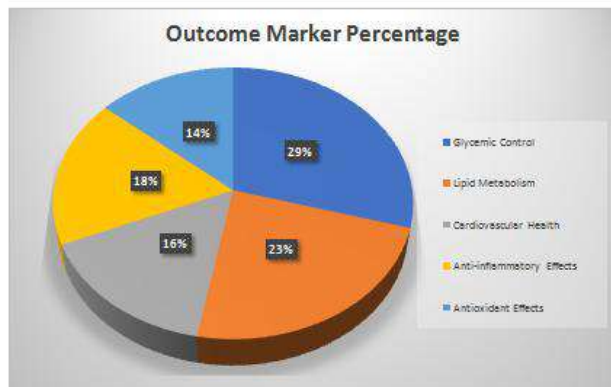


Figure 4: Chart Showing the Outcome Markers for the Included Studies

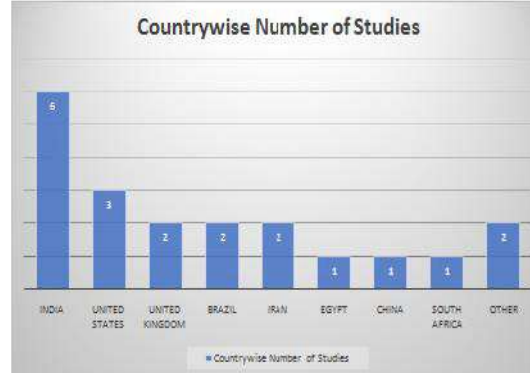


Figure 5: Chart Showing the Country-wise Number of Studies Included

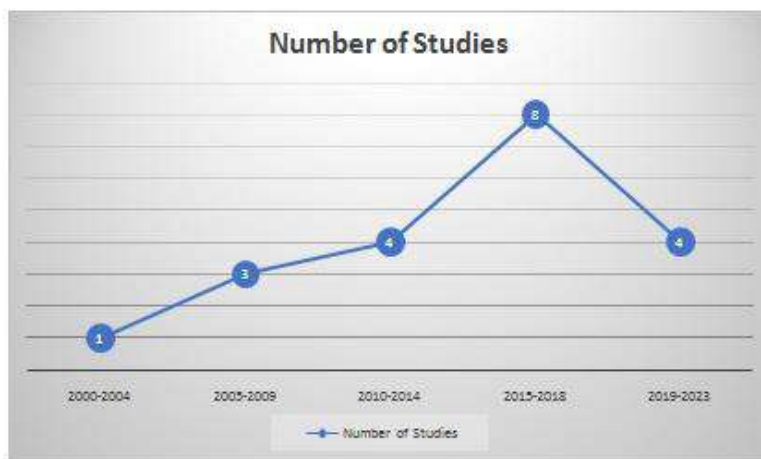


Figure 6: Chart Representing the Year-wise Distribution of the Included Studies





An Open Clinical Evaluation of Vasambu Patru (Semi-Solid Polutice) in the Management of Azhal Keelvaayu (Osteoarthritis-Knee) - A Pilot Study

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ABSTRACT

This study aimed to determine the clinical efficacy of Vasambu Patru external therapy in reducing pain in patients diagnosed with Azhal Keelvaayu or Osteoarthritis. A group of ten patients was selected to participate in the study, and they were administered the trial therapy over fifteen days. The participants were selected based on the inclusion and exclusion criteria of the study. The pain level was assessed using the Visual Analogue Scale before and after treatment. The average values of the Visual Analogue Scale were evaluated to be 6.6 before the administration of the trial therapy and 2.6 after the therapy, indicating a significant reduction in pain. This study indicates a pressing need to increase awareness and understanding of Siddha external therapy. Patients with knee osteoarthritis have been found to benefit from Vasambu patru potentially. So, the study may be undertaken with the same trial therapy in a large number of samples and it may throw new light on the treatment of Azhal Keelvaayu.

Keywords: Vasambu, patru (poultice), External therapy, Osteoarthritis, Acorus calamus, Siddha



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INTRODUCTION

osteoarthritis, commonly called as Azhal Keelvaayu, is the most prevalent form of arthritis and a chronic degenerative joint disease. In addition to developing new bone and reshaping the joint's contour, this condition is marked by the localized loss of articular hyaline cartilage. Osteoarthritis is one of the most prevalent chronic arthritic disorders and is the leading cause of pain and disability in many nations worldwide. The World Health Organization (also known as the WHO) estimates that in the world, 18.% of women and 9.6% of men over 60 have symptomatic osteoarthritis[1]. Between 2000 and 2020, knee OA was very common worldwide, which could put a strain on the world healthcare system. OA is more common in women than in men. Over 15 million persons in India suffer from osteoarthritis, the most common type of arthritis. It is one of the top five most common diseases in India[2]. South India is the place of origin of the old indigenous medical system known as Siddha medicine. In Siddha literature, thirty-two distinct treatment processes are used as external remedies. One of the 32 external therapies that have been traditionally used for alleviating problems including arthritis, sprains of the muscles, swellings, abscesses, and other related conditions is PATRU. It involves covering the affected area with a soft, moist poultice consisting of a semi-solid paste prepared by grinding plant fragments or unprocessed raw medications. As per Siddha literature,

Vasambu patru plays a vital role in treating Azhal keelvaayu[5]. Hence, the study evaluated **Vasambu Patru's** efficacy in managing OA knee symptoms.

IEC approval: The IEC (Institutional Ethical Committee), Government Siddha Medical College, Chennai –600106 reviewed and approved the study protocol and informed consent. IEC NO:GSMC-CH-1243/ME-II/040/2023

CTRI No: This trial was also registered in the Clinical Trial Registry of India (CTRI), CTRI NO: CTRI/2023/08/056965.

MATERIALS AND METHODS

The pilot study was conducted at Government Siddha Medical College, Chennai.

CTRI approval

This trial was also registered in the Clinical Trial Registry of India (CTRI), CTRI NO: CTRI/2023/08/056965. This study was initiated only after CTRI REGISTRATION.

MATERIALS AND METHODS

The pilot study was conducted at Government Siddha Medical College, Chennai.

CTRI approval

This trial was also registered in the Clinical Trial Registry of India (CTRI), CTRI NO: CTRI/2023/08/056965. This study was initiated only after CTRI REGISTRATION.

Patient consent

Informed consent was obtained from all individual participants included in the study. The study was conducted by the Declaration of Helsinki, and the protocol was approved by the IEC (Institutional Ethical Committee), Government Siddha Medical College, Chennai –600106 (Approval No. IEC NO: GSMC-CH-1243/ME-II/040/2023). They reviewed and approved the study protocol and informed consent. All participants were assured of the confidentiality of their personal information, and participation was entirely voluntary with the option to withdraw from the study at any time.



**Adlin Reshma et al.,****Enrolling of patients**

Patients who matched the criteria for enrolment were allowed to participate or take part in the study. The study's objectives, potential outcomes, and trial medication were disclosed to the participants who were recruited for the research. Trial therapy was carried out for fifteen days. Data from baseline assessments as well as pre- and post-assessments were gathered. Records were kept of the analytical statistics and outcomes.

INTERVENTION - Vasambu patru

STUDY DESIGN - Pilot study

STUDY PERIOD - 15 days

STUDY DURATION - 3 months

SAMPLE SIZE - 10 patients

STUDY PLACE - Arignar Anna Government Hospital of Indian Medicine, Government Siddha Medical College (GSMC), Chennai 106.

Sampling technique

The data was collected by consecutive sampling among persons accompanying patients attending the OPD at Arignar Anna Government Hospital of Indian Medicine, Chennai.

Eligibility criteria

There were 10 patients included in this study, and subjects were enrolled based on inclusion and exclusion criteria.

Inclusion criteria

Age limit - 31 to 70 years, all genders, Pain, and swelling in the joint, Early morning stiffness (less than 15 mins), Reduced range of motion in the knee joint

Exclusion criteria

Rheumatoid arthritis (RA), Psoriatic arthropathy, Gouty Arthritis, Septic arthritis, Fracture, and Any other serious systemic illness will be excluded clinically or based on available medical reports. All collected data were entered into MS EXCEL SOFTWARE using different columns as variables and rows as patients, SPSS software was used to perform the statistical analysis. A probability value of <0.05 was considered as indicated as statistically significant.

RESULTS

10 patients presented with complaints of OA-knee were included in the study and were given the trial therapy. The baseline data was collected along with demographic details of the patients. Results were observed to the following criteria.

1. GENDER
2. AGE DISTRIBUTION
3. OCCUPATION
4. BMI
5. VISUAL PAIN ANALOG SCALE
6. STATISTICAL ANALYSIS

Demographic profile**Gender**

In the study, 70% of the participants were females and the remaining 30% were males

Age distribution

30% of participants were distributed in 41-50, 40% were in 51-60%, 20% were distributed in the 61-70 age group, while only 10% fell within the 31-40 age group.



**Adlin Reshma et al.,****Occupation**

Out of 10 patients, 40% of the participants were Home Makers, 30% were Teachers and 30% were private employees like security guards and hotel servants.

Body mass index

30% of the participants had normal BMI 30% were Over Weight and the remaining 40% were Obese.

Visual pain analogue scale

Among 10 patients, 2 cases (20%) were on a pain scale of 4, 1 case (10%) was on a pain scale of 5, 6 cases (60%) were on a pain scale of 6, and 1 case (10%) was on pain scale 7 before treatment. Out of 10 patients, 1 case (10%) was in pain scale 2, 3 cases (30%) were in pain scale 3, 3 cases (30%) were in pain scale 4, and 3 cases (30%) were in pain scale 5 respectively after treatment.

Statistical analysis

Before treatment Min, Max, and mean values (4, 7, 5.6) after treatment the above values (2, 5, 3.8) are reduced and the p-value is **0.004**. Since the p-value is less than 0.05 it is statistically significant, that shows the VASAMBU PATRU is acting against the OSTEOARTHRITIS – KNEE.

DISCUSSION

Patru is one of the 32 external therapies practised in ancient Siddha treatment and it is placed second in the series of external therapies. Patru, a semisolid paste is obtained from plant extracts or by grinding crude raw drugs and applied as a thick paste over the affected region. Before initiating the study, the protocol along with informed consent was designed and submitted to INSTITUTIONAL ETHICAL COMMITTEE and after approval from members of the IEC, the trial was registered in the CLINICAL TRIAL REGISTRY OF INDIA. After the arrival of CTRI number CTRI/2023/08/056965, the trial was started. The trial therapy of Vasambu Patru has been evaluated by administering it to 10 patients externally for 15 days. Vasambu Patru has been chosen for the trial under the rationale that the literature review of the Siddha classical book recommends the use of a semi-solid poultice of powdered vasambu and kaachukatti for treating joint pain. The anti-inflammatory and analgesic actions of Vasambu and kaachukatti have been proved in previous studies and the review of Siddha literature suggests the same. Hence, based on the above-mentioned references and the research works it justifies the beneficial treatment of Azhal Keel Vaayu (OA-knee). The following data were collected during enrolment:

Distribution of cases by gender

Among 10 patients of Azhal keel Vaayu, 7 patients (70%) were females and 3 cases (30%) were males (Table 1.1). According to the World Health Organization (WHO), 9.6% of men and 18% of women aged over 60 years have symptomatic osteoarthritis worldwide^[1]. This study shows women are more prone to OA than men.

Distribution of cases by age

Among 10 patients, 30% of participants were distributed in 41-50, 40% were in 51-60%, 20% were in the 61-70 age group, while only 10% fell within the 31-40 age group (Figure 1.1). The global prevalence of knee OA was 16.0% in individuals aged 15 and over and 22.9% in individuals aged 40 and over. Similarly, there are around 654.1 million individuals i.e. 40 years and above, with knee OA in 2020 worldwide^[2]. This study shows that above 40-year-olds are more prone to OA-knee.

Distribution of cases by occupation

Out of 10 patients, 40% of the participants were Home Makers, 30% were Teachers and 30% were private employees i.e. conductors, security, and hotel servants. Occupation takes a major part of our day. One of the most common occupational risk factors for OA knee is a heavy physical workload. Other risk factors like frequent exposure to





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oppressive biomechanical stresses such as bending of the knee joint, kneeling or squatting, prolonged standing greater than 2hrs/day, regular stair climbing, heavy weight lifting greater than 10 kg, jumping, and vibration. Occupation is one of the major risk factors for OA^[3]. This study reveals the significant occupation-related risk factor for OA (Figure 1.2).

Distribution of cases by BMI

In this study, 30% of the participants had normal BMI 30% were Over Weight and the remaining 40% were Obese. Coggon et al reported that subjects with a Body Mass Index of more than 30kg/m² were 6.8 times more likely to develop knee Osteoarthritis than the subjects who were under normal weight. The impact of body mass index (BMI) on the incidence of knee OA was assessed in a recent meta-analysis, including both cohort and case-control studies by Jiang et al. Obesity is the highest alterable risk factor for OA. Obesity contributes to the incidence and progression of OA, with the strongest relationship being at the knee. Weight reduction improves both symptoms of Osteoarthritis and can reduce disease progression.^[6] The current evidence points to obesity-related Osteoarthritis as both their problem of excessive weight loading in the knee joint and hormonal and cytokine dysregulation (Figure 1.3).

Changes in visual pain analogue scale

From the VPA Scale,

1. 4 cases (40%) changed from moderate to mild level
2. 1 case (10%) changed from severe to moderate level
3. 5 cases remained at a moderate level.

According to Figures 1.4 & 1.5, Before treatment Min, Max, and mean values (4, 7, 5.6) after treatment the above values (2, 5, 3.8) are reduced and the p-value is **0.004**. Since the p-value is less than 0.05 it is statistically significant, which shows the VASAMBU PATRU is acting against the OSTEOARTHRITIS – KNEE.

Statistical analysis

The p-value <0.05 for the Visual Pain Analog Scale, thus it is statistically significant. All collected data were entered into MS EXCEL SOFTWARE using different columns as variables and rows as patients, SPSS software was used to perform the statistical analysis. A probability value of <0.05 was considered as indicated as statistically significant.

From this study, it is evident that the trial external therapy showed good results in treating AZHAL KEEL VAAAYU (OSTEOARTHRITIS – KNEE) by reducing pain significantly. Based on changes in the Visual Analogue Scale, out of 10 cases, 4 cases (40%) changed from moderate to mild level, 1 case (10%) changed from severe to moderate level, and 5 cases remained at a moderate level. The clinical study's findings show that the trial therapy was clinically beneficial for treating osteoarthritis in the knee. This study's objective was to present baseline data that demonstrate Vasambu Patru's clinical efficacy in treating OA knees with external treatment. Notable amelioration was observed in a limited cohort of individuals who received Vasambu Patru. There was no adverse reaction noted while receiving therapy. Therefore, I conclude that this study of the clinical evaluation of Vasambu patru (semi-solid poultice) in the treatment of osteoarthritis – Knee has a major role in symptom reduction for patients with Azhal Keel Vaayu. So, the study may be undertaken with the same therapy in a large number of cases and it may throw new light on the treatment of Azhal Keel Vaayu.

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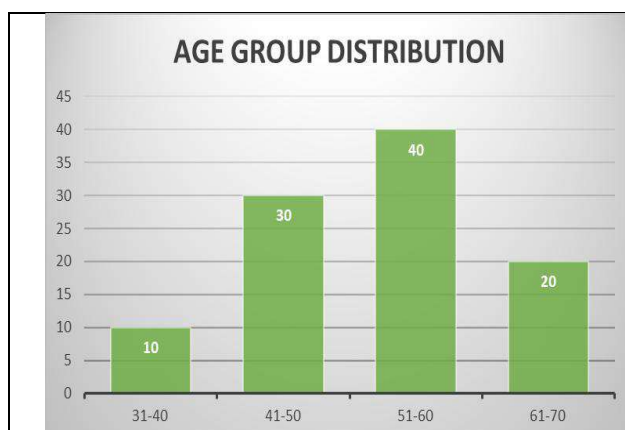
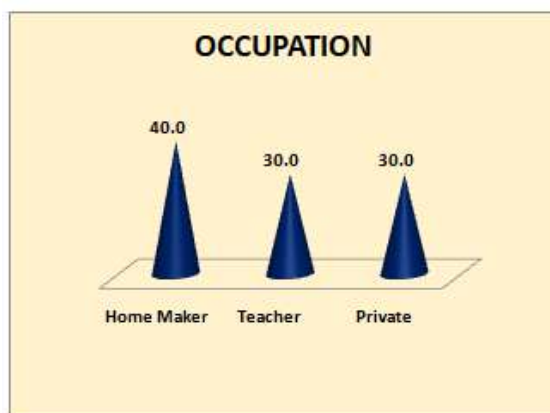
Table 1.: Distribution of the sample patients according to

Gender	No. of patients	Percentage
Male	3	30%
Female	7	70%

Table 2: statistical analysis of the VPA scale**VISUAL PAIN ANALOG SCALE:**

Statistical analysis is done by using Wilcoxon signed rank test,

VISUAL PAIN ANALOG SCALE	N	MEAN	SD	MINIMUM	MAXIMUM
B.T	10	5.6000	.96609	4.00	7.00
A.T	10	3.8000	1.03280	2.00	5.00

**Figure 1: Distribution of the sample patients according to Age****Figure 2: Distribution of the sample patients according to OCCUPATION**



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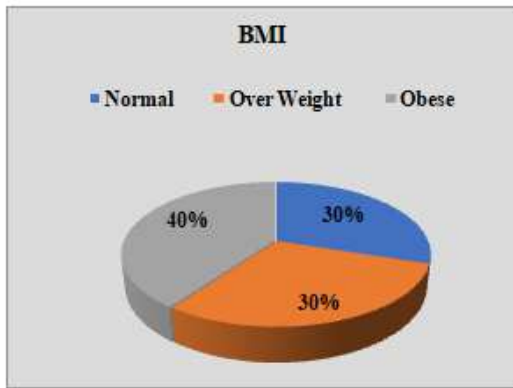


Figure 3: Distribution of the sample patients according to BMI

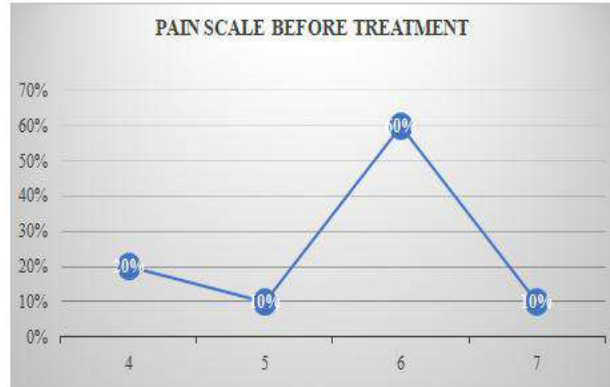


Figure 4: Distribution of the sample patients according to Visual Pain Analog Scale score (before treatment)

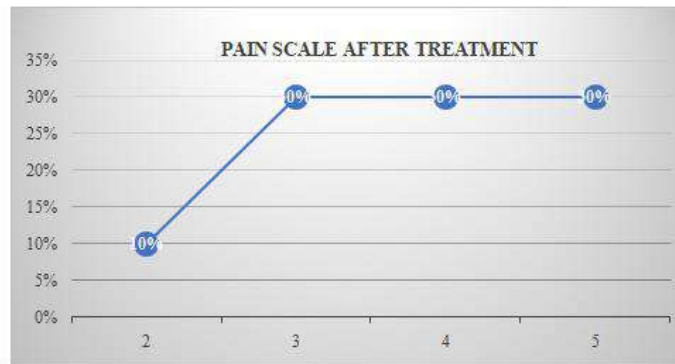


Figure 5: Distribution of the sample patients according to Visual Pain Analog Scale score (after treatment)





Efficacy of Commercial Soaps in Inhibiting Skin Pathogens: An Agar Well Diffusion Study

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ABSTRACT

The present study evaluates the antimicrobial activity of various soaps against the pathogens found on the exterior of skin surface like *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Escherichia coli* using Agar Well Diffusion Method. Every human skin and mucous membranes are habitat to a variety of microbiota from the instant moment of birth until death. A vast variety of microflora is found on human skin that gives birth to skin infections, also enter our internal organs and damage them under unfavorable conditions. In the context of this antimicrobial activity of different soaps was studied on such micro-organisms that can prevent these infections. While determining the results it revealed that all soaps contain antimicrobial activity and kill microbes to large extent. The acquired results demonstrated that the test organisms were sensitive to soap samples at various concentrations. All soaps showed better and similar Zone of Inhibition against these pathogens. Highest efficiency to kill microbes was shown by Melashine and Dettol for *P. aeruginosa* whereas Twinkle followed by Melashine were most effective against both *Staphylococcus aureus* and *Escherichia coli*.

Keywords: Antibacterial activity, Antiseptic and herbal soaps, Skin flora pathogens, S. Aureus, E. Coli, P. Aeruginosa.





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INTRODUCTION

The skin of every individual has a normal micro flora, or surface microorganisms. (Prescott & Associates, 2008).(1) The adult human body is made up of 10¹⁴ cells, of which 10% make up the body proper and 90% are made up of microflora.(2) The protective layer of body (skin) and mucous membranes are residence to a variety of microbiota from the instant moment of birth until death. Different species occupy different bodily sites at different times over an individual's life, indicating that the normal microbial flora is very stable. The steady populations of bacteria that make up the typical adult flora are frequently the result of some organized process or succession, in which the normal flora in humans normally develops after birth.(3) The skin, being the most exposed area of the body, is susceptible to foreign particles that can cause a variety of skin-related illnesses.(4) Skin infections are caused by gram negative and gram positive bacteria that are placed on the skin layer by the environment. Example of these bacteria includes *Staphylococcus aureus*, *B. subtilis*, *P.aeruginosa* and *E coli*. (5) Therefore, to protect the skin from a variety of ailments, it is necessary to maintain appropriate hygiene and cleanliness for the body's most exposed areas and to stop microorganisms from spreading throughout the environment.(4) The first line of protection against germs, pathogens that can prompt flu, colds, skin infections, even deadly communicable diseases is cleaning your hands and body, especially using soaps(6) Proper washing of hands with soap and water has been the "gold standard" for abolishing the majority of resident and transient bacteria from the hands (Foddai et al., 2016). (7)Among the substances with antimicrobial activity against bacteria, particularly those on the skin are soaps. Many authors have given alternative definitions of soap. Some have defined it as cleansing agent that is created in the form of granules, bars, flakes, or liquid by reacting salts of potassium or sodium with different fatty acids that are naturally occurring (salt of non-volatile fatty acids).(8) Soaps are made up of oils, fats (vegetable or animal origin), and salts. Soaps are typically salts generated by saponification of alkaline material with free fatty acids in fat and oil. (9)Even though the main ingredients of soap include fat, oil and detergents (added to boost the antibacterial properties of soap).(10) These soap qualities include protecting against skin conditions (such as rashes, eczema, and scabies), leaving the skin feeling soft and rich in lather management of skin infections (like ring worm) safeguarding the skin's smoothness and even tone.(11)Good components that may destroy bacteria without harming bodily tissues should be present in the soap.(12) As antimicrobial compounds are included in antiseptic soaps, they help stop the spread of infection by these bacteria. However, excessive soap use can cause antimicrobial resistance and increase person's susceptibility to allergies as well as skin rashes.(13)

MATERIALS AND METHODS

Study Design and Settings

This study was conducted from April to June 2024 at School of Life Sciences Microbiology Lab Starex University Gurugram.

Sample Collection

Different types of soap samples, which people often utilize, was purchased from standard pharmaceutical shops from Manesar (Gurugram).

Every soap's contents and expiration date was recorded. The list of soap includes Margo, Twinkle, Dettol, Savlon , Medimix, Melashine.

Test Organism

The bacterial cultures employed in this investigation include, *Staphylococcus aureus* (ATCC 25923) [14], *Pseudomonas aeruginosa* (ATCC 27853)[15] and *Escherichia coli* (ATCC 25922). [16]

Preparation and dilution of soap sample extract

A sterilized, sharp knife was used to remove soap off one side. 100mg, 250mg and 500mg of every sample of soap was measured and dissolved in 1ml of sterile distilled water individually in different sterile test tubes.



Shrikant Yadav *et al.*,**Media preparation**

The media and peptone was obtained in the commercially organized powered (dehydrated) form and was arranged according to the manufacturer's information. Specified amount of each powered media was reconstituted in individual quantity of distilled water in a conical flask and mixed appropriately by shaking. The flask was then stopped and sterilized by autoclaving at 121°C and 15 psi for 15 minutes. After cooling to 45°C in a water bath, the autoclaved medium was dispensed into Petri dishes that had already been sterilized and left to harden. While the reconstituted peptone water was poured into test tubes.

Inoculum Preparation

After cooling, the ATCC strain of *S.aureus*, *P.aeruginosa* and *E.coli* was inoculated in peptone and incubated at 37°C for 24 hours. Sample was taken from incubated peptone and lawn sample on prepared MHA plates with the help of swab stick. An overnight culture in peptone was kept set for antimicrobial activity. The Agar well diffusion method was used to test the antibacterial activity of soaps.

Agar well Diffusion method

The experiment was conducted using the agar well diffusion technique. The prepared molten agar was permitted to solidify for 20 minutes, 6mm cup borers was used to bore five (5) holes in the media plates at specific intervals, and samples of soap in various quantities was added and labeled after being inserted into the drilled holes. The plate was left to stand at room temperature for a minimum of half an hour in order to ensure adequate diffusion, following that, each soaps was incubated for 24 hours at 37°C. After incubation, the consequent diameter of the zone of inhibition was determined and reported.

RESULTS AND DISCUSSIONS

The study's findings showed that the majority of soaps exhibit antimicrobial action, although to differing degrees, as demonstrated by the isolate's growth pattern being inhibited. Every antimicrobial soap provides a distinct zone of inhibition at a different dose for a particular bacterium, according to a comparison of the soaps' efficiency using the well agar diffusion technique. Microorganisms found in normal human skin can be classified as resident and transitory flora.[17] Microbes differ in their nutritional supplies and stage of susceptibility to antimicrobial agents. The impact of soap on the skin's microflora remains relatively underexplored. No soap contains a universally suitable ingredient that meets the needs of all skin types. Individual skin responses vary from soap to soap since the skin is the primary location where soap exposure is highlighted in this case. [18] In most cases, soaps are used to clean and remove dust and bacteria from the skin's surface. The selection of soap varies from people to people but it should not have an effect on the sensitive skin and it should be helpful against infection causing microbes present on skin.[19]

The current study was conducted in order to ascertain the antibacterial effectiveness of soaps such as Savlon, dettol, Margo, Medimix, Twinkle, Melashine against skin microfloras important microorganisms which is *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *E.Coli*. Antimicrobial activities of all the six soaps against selected bacterial strains (*S.aureus*, *P.aeruginosa* and *E.coli*) was recorded in the form of inhibition zone and measured in millimeters. The antibacterial activity of various soaps was tested against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli* using the zone of inhibition method. The results indicated that all soaps showed increased antibacterial activity with higher concentrations. Among the soaps, Melashine demonstrated the highest efficacy across all three bacterial species, with the largest zone of inhibition recorded at 500 mg concentration. For *Staphylococcus aureus*, Melashine achieved a zone of 21 mm, followed by Twinkle at 24 mm, while Dettol showed the least activity with a 12 mm zone. Against *Pseudomonas aeruginosa*, Melashine again had the highest zone of 20 mm at 500 mg, with Dettol close behind at 18 mm, and Margo being the least effective. For *Escherichia coli*, the inhibition zones were generally smaller, with Melashine showing the highest activity of 18 mm at 100 mg, while other soaps like Margo and Medimix exhibited minimal activity with zones around 10-11 mm. Across all tests, the positive control antibiotics, including Linezolid, Ciprofloxacin, and Azithromycin, showed significantly larger zones of inhibition compared to the soaps, confirming their superior antibacterial effectiveness. Negative controls showed no inhibition, validating the results. These



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findings highlight the variability in soap efficacy against different bacteria and the critical role of antibiotics in combating bacterial infections. When we compare our study with G.B.Patel Science and S.T.S.K.V.S Commerce College, the results revealed that among the antiseptic soaps highest efficacy was performed by Dettol and Lifebuoy Plus soaps against Gram positive isolates but in Gram negative isolates Dettol and Savlon had maximum bactericidal activity.(19) One more study from Mehta Science College showed that comparative study between non medicated and medicated soaps, it was observed that medicated soaps showed the highest inhibition against *Staphylococcus aureus* in comparison to non medicated soaps.(21) The indicated soap in this study contains some active antimicrobial agents like chloroxylenol. These substances work by denaturing everything, which interferes with microbial metabolism and disrupts cell activity. These based on a number of factors such as the contact time, the inherent properties of the organisms, concentration of individual formulation and skin sensitivity.[19] The experimental data findings show that the majority of the antiseptic soap has antimicrobial activity, thought to varying degrees as showed by the inhibition of growth outline of the isolates. This study clearly demonstrated that the Gram-positive bacterium *Staphylococcus aureus* was inhibited by all the soaps tested, in contrast to the Gram-negative bacteria. According to the work, some resistance developed once the agent was applied repeatedly. Therefore, washing hands before eating, after a patient examination, and before surgery is standard practice to eliminate some potentially hazardous temporary flora and decrease a number of resident flora that could lead to infection chances.(20)

CONCLUSION

The most important aim of this study was to determine the antimicrobial activity of 6 various soaps Dettol, Savlon, Margo, Medimix, Twinkle, Melashine. The result shows that all soaps give different zones of inhibition at different concentrations. Soaps are common cleaning products used to clean and eliminate germs. Soaps break down the proteins and membranes of microorganisms. The zone of inhibition varied significantly across all soap types used in the study. Hence Dettol followed by savlon among other soaps commonly utilized to prevent skin diseases and transmission of skin pathogens when utilized in hand washing. However, prolonged utilize of these soaps could potentially result in microbial resistance and skin allergies. Active germicidal chemicals are present in antiseptic and medicinal soaps; it eliminates infections; however extended use should be avoided. As herbal soaps like Margo, Medimix and other soap like Twinkle and Melashine revealed similar or more antibacterial properties similar to those of medicated or antiseptic soaps, some extra elements make them more effective and better in our day-to-day lives/component which is beneficial for our skin in other aspects like gentleness, softness and glowing skin. The soap is an everyday need, however, it should contain effective active ingredients or plant-derived extracts it should be capable of killing bacteria without causing harm to body tissues, even with regular use.

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Table 1:"Zone of Inhibition Diameter (mm) of Staphylococcus aureus Using Various Soaps and Antibiotics"

Zone of Inhibition						
Soaps	Margo	Twinkle	Medimix	Dettol	Savlon	Melashine
Concentration						
100mg	10	17	11	10	11	17
250mg	12	20	14	10	11	18
500mg	12	24	15	12	14	21
Controls						
Positive control Antibiotic (Linezolid)			Negative control (sterile disc)			
25mm			0/ NA			



Shrikant Yadav *et al.*,**Table 2: "Zone of Inhibition Diameter (mm) for Pseudomonas aeruginosa Using Various Soaps and Antibiotics"**

Zone of Inhibition						
Soaps	Margo	Twinkle	Medimix	Dettol	Savlon	Melashine
Concentration						
100mg	10	14	10	16	15	17
250mg	12	16	13	17	16	18
500mg	18	16	15	18	17	20
Controls						
Positive control Antibiotic (Ciprofloxacin)				Negative control (sterile disc)		
27mm				0/ NA		

Table 3: Diameter of Zone of Inhibition (mm) on E. Coli by various soaps and Antibiotic

Zone of Inhibition						
Soaps	Margo	Twinkle	Medimix	Dettol	Savlon	Melashine
Concentration						
100mg	10	15	10	10	10	18
250mg	10	18	10	10	11	17
500mg	11	16	10	10	12	16
Controls						
Positive control Antibiotic (Azithromycin)				Negative control (sterile disc)		
19mm				0/ NA		





A Study on Urinary Tract Infections among Adults in Western Uttar Pradesh

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ABSTRACT

Urinary Tract Infection (UTI) in general can be termed as the symptomatic presence of microbial pathogens in the urinary tract. It is found to be one of the most common and frequent bacterial infections. These infections can vary in severity from mild cystitis or inflammation of the bladder, to severe cases of uroseptic shock. It is found in all age groups and sexes. The incidence of UTI is more common in female than male. UTI can be classified into Complicated UTI and Uncomplicated UTI, and depending upon the cause it can also be distinguished into Community acquired and Hospital acquired. Few examples of common causative agent are *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Enterobacter spp*, *Proteus mirabilis*, *Enterococcus faecalis* and some *Candida spp*. The economic burden of these diseases could rise significantly due to high recurrence rates and rising antibiotic resistance in Uropathogens. Based on specific risk factors, a focused history is used to diagnose UTI and relevant investigations are conducted. UTI is a serious health problem if untreated, early diagnosis and treatment with antibiotic is mainly recommended. This study aims to estimate the prevalence rate of UTI among adults of western UP between the age group of 20-70.

Keywords: Symptomatic, Uropathogens, Complicated UTI, Uncomplicated UTI





INTRODUCTION

Urinary Tract Infection (UTI) is an infection of the urinary system. It is a bacterial infection which affects different parts of the urinary tract (**Demelie *et al.*, 2012**). The urinary tract consists of the kidneys, ureters, urinary bladder and urethra. Bacterial invasion of the urinary system is typically the source of infection. It is diagnosed when there is an overgrowth of bacteria in the urinary tract (**Czajkowski *et al.*, 2021**). UTI has the potential to induce sepsis, a condition that poses a risk to life; however, the majority of infections exhibit less severity. It is also found to be one of the most common bacterial infections and affects around 150 million people worldwide each year. Most people experience UTI at least once in their lifetime (**Mlugu *et al.*, 2023**). UTI affects both male and female, but females are more commonly affected (**Flores-Mireles *et al.*, 2015**). Women are more prone to UTI because of their anatomy as they have shorter urethral length and due to the presence of vaginal cavity (**Tan *et al.*, 2016**). UTI can be classified mainly into Lower or Upper UTI or Complicated or Uncomplicated UTI (**Sheerin *et al.*, 2011**). Complicated UTI (CUTI) can be defined as those associated with urinary tract abnormalities that increase susceptibility to infection, whereas, Uncomplicated UTI (UUTI) are those which affects healthy patients in the absence of neurological abnormalities (**Klein *et al.*, 2020**). It can also occur in two forms such as symptomatic and asymptomatic infection. Symptomatic bacteriuria are those which shows symptoms, whereas, Asymptomatic bacteriuria are those which occurs without showing symptoms. These infections arise due to the development and expansion of microorganisms within the urinary tract (**Mandokhail *et al.*, 2015**). Symptomatic UTI's are further classified into upper and lower infections (cystitis) and (pyelonephritis) (**Hooton *et al.*, 2012**). Upper UTI impact the kidneys and ureters, as seen in the case of pyelonephritis, whereas lower UTI's affect the urethra and bladder (**Kaur *et al.*, 2021**). Numerous risk factors are correlated with cystitis, such as the female gender, sexual activity, diabetes, vaginal infections, a history of UTI, obesity and genetic predisposition (**Foxman *et al.*, 2014**). UTI can also be community acquired or hospital acquired according to the source of infection. Urinary Tract Infections (UTI's) can be attributed to a variety of microorganisms like Gram-positive and Gram-negative bacteria as well as certain fungi. Uropathogenic *Escherichia coli* (UPEC) stand out as the predominant causative agent for both uncomplicated and complicated UTI's (**Kline *et al.*, 2011**). The other common causative agents are *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Staphylococcus saprophyticus*, *Enterococcus faecalis*, group B *Streptococcus*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Candida species*. (**Levison *et al.*, 2013**)

MATERIALS AND METHODS

This study was carried out at the Department of Paramedical Sciences, Subharti Medical College, Swami Vivekanand Subharti University, in association with Central Laboratory of Chhatrapati Shivaji Subharti Hospital, Meerut.

Sample Collection and processing

Antibiotic Susceptibility Testing (AST)

Antibiotic Susceptibility Testing of all the organisms were done by VITEK-2

Inoculums preparation

- Two scratch-free VITEK unsensitized (polystyrene) tubes were taken. The first tube is usually marked for ID and the second tube is for AST.
- At least 3 ml of sterile saline must be transferred into the unsensitized tube using a saline dispenser aseptically.
- Using sterile cotton swabs or sterile loops, a homogenous organism suspension was prepared by transferring several isolated colonies from the plates to the saline tube. The bacterial strain was rubbed to the internal surface of tube.
- Swab stick moistened with saline in tube was again rubbed to make a smooth paste. The bacterial suspension was uniformly mixed with saline in tube.
- Mix well using pipette with only sterile tips.
- The suspension was adjusted to the McFarland recommended for GP (0.50-0.63 McFarland) ID and AST.



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RESULTS AND DISCUSSION

A total of 231 urine samples were collected from the clinically suspected patients of UTI. Data of all the patients were taken during the study period of six months. Out of the total urine samples collected, clinically significant pathogens were grown in 87 samples comprising 37.67% of overall culture positivity among urine samples. The distributions of positive and negative specimen are shown in the table and figure given below.

Distribution of Causative organisms

Out of total 87 urine culture positive samples, bacteria were isolated from 63(72%) and Fungi were isolated from 24(28%). The numbers of bacterial and fungal growth are shown in the table given below.

Distribution of Gram-Positive, Gram-negative and Candida species

Out of total 87 isolates grown on culture from urine specimen, most of the isolates were bacteria, out of which Gram positive bacteria (GPB) isolates were found to be 16 (18%) ,Gram negative bacteria (GNB) were found to be 47 (54%) and *Candida* species were found to be 24 (28%). The distribution of GPB, GNB and *Candida* species are shown in the table and figure given below.

Distribution of bacteria on the basis of positive samples

Out of total 87 isolates grown on culture from urine specimen, 63 isolates were found to be bacteria. Gram-positive bacteria were found to be 16 in number and Gram-negative were found to be 47 in number. *Enterococcus faecium* were found in 7 isolates, *Acinetobacter baumannii* in 4 isolates, *Enterococcus avium* in 1 isolate, *Escherichia coli* in 23 isolates, *Enterococcus faecalis* in 4 isolates, , *Enterococcus gallinarum* in 3 isolates, *Klebsiella pneumoniae* in 13 isolates, *Pseudomonas aeruginosa* in 5 isolates, *Myroides* in 1 isolate, *Proteus mirabilis* in 1 isolate and *Staphylococcus hominis* in 1 isolate. *E.coli* was found to be the commonest causative agent of UTI.

Distribution on the basis of gender

Out of 87 positive sample, female with positive samples were found to be 47(54%) in number while male were found to be 40 (46%) in number. Female were found to be more affected by UTI than male. The distribution is shown in the table and figure given below

Age-wise distribution of UTI patients

Maximum numbers of isolates were seen in age groups of 40-50 years, followed by 50-60 years. Minimum numbers of isolates were seen in age group of 20-30 years, as shown in the table and figure given below.

Antibiotic Susceptibility Pattern of bacterial isolates

Out of the 63 positive bacteria samples, it was found that the pathogens were mostly sensitive to Nitrofurantoin and mostly resistant to Ciprofloxacin as shown in the table given below.

Anti-fungal susceptibility pattern of *Candida* isolates

Out of the 24 positive samples, it was found that *Candida* species were mostly resistant to Fluconazole, and intermediate to Fluconazole. They were mostly sensitive to VORI, Amp-B, and FLC as shown in the table given below. Urinary tract infection is one of the commonest infections of the urinary tract caused by microorganisms. It affects people of all age and all sexes around the world. It is one of the leading microbial infections in the world.

A total of 231 urine culture samples received during the study period were analyzed. The urine culture positivity rate in our study was found to be among 87 cases i.e 37.67%. A study conducted by **Odoki *et al* 2019** also shows similar positivity rate of 32.2%, a study conducted by **Kabugo *et al* 2016** also shows similar positivity rate of 38%. Whereas, a study conducted by **Tibyangye *et al* 2015** shows significantly lower rate 22.33%. There may be variation in urine culture positivity rate due to many factors such as disruption of micro flora of patients or sample contamination.





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This present study shows that Gram-negative bacteria made up 54% of the isolates. Similar study with a higher positivity rate of 85.20% gram-negative bacteria was shown by **Serretielloet al 2019**. Our present study shows *E.coli* as the most prevalent bacterial uropathogen with 23 (36%) out of 63 positive samples. A study conducted by **Rajendran et al 2017** also shows *E.coli* as the most prevalent with a similar positivity rate of 35.5%. In species wise distribution of bacterial isolates our study showed that *E.coli* (36%) was the most frequent isolate followed by *Klebsiella pneumoniae* (21%), *Enterococcus faecium* (11%), *Pseudomonas aeruginosa* (8%), *Acinetobacter baumannii* (6%), *Enterococcus faecalis* (6%), *Enterococcus gallinarum* (5%), *Proteus mirabilis* (2%), *Myroides spp* (2%), *Staphylococcus hominis* (2%) and *Enterococcus avium* (1%). Slightly similar results has been shown in a study done by **Mancuso et al 2023** where *E.coli* was the most common bacterial isolate followed by *Klebsiella pneumoniae*, *Enterococcus spp.*, *Pseudomonas aeruginosa*, *Proteus mirabilis* and *Staphylococcus spp.* A study done by **Badiger et al** also shows similar findings where *E.coli* was the most frequent isolate followed by *Klebsiella pneumoniae* and *Enterococcus spp.* This study shows that *Candida spp.* is one of the most common fungi which can cause UTI. In the present study it was shown that 24 out of 87 positive isolates were *Candida spp.* A study done by **Komala et al 2013** also shows that *Candida spp.* are the most common fungal isolates. In the present study, women (54%) were found to be more prone to UTI than men (46%), which is similar to a study conducted by **Hooton et al 2012**. A study conducted by **Pardeshi et al 2018** also shows that growth in women 66.78% were found to be more than male 33.22%. A study done by **Mlugu et al 2023** also found a higher prevalence rate of UTI in women than men ($p=0.05$). UTI usually occurs more in female due to their anatomy as they have shorter urethra which is close to the perineum, than men.

In this current study it was shown that Urinary Tract Infection positivity rate was seen mostly between the ages of 40-60 years. According to recent studies done by **Rodriguez-Manas et al 2020** the elderly have an increased risk of contracting UTI in comparison to younger people. The resistance pattern of bacteria and fungi is ever changing and varies in different geographical areas. In this study it was found that bacterial isolates were mostly sensitive to Nitrofurantoin, **Badiger et al 2021** study also shows that bacterial isolates were sensitive to Nitrofurantoin. On the contrary a study done by **Mlugu et al 2023** displays moderate resistance rate of Nitrofurantoin (37%). According to study done by **Johansen et al 2011** it shows much higher resistance rate of Nitrofurantoin. The bacterial isolates in this study shows high resistance rate of 78% for Ciprofloxacin, whereas a study done by **Mlugu et al 2023** shows moderate resistance rate of 37%. A study done in Tanzania shows that Ciprofloxacin was the drug of choice for UTI. Regarding antifungal susceptibility our study shows that most of the isolates showed higher level of sensitivity towards Voriconazole (91%), Amphotericin-B (91%) and Flucytosine (91%). Similar study by **Yashavanth et al 2013** shows that *Candida* isolated showed sensitivity towards Amphotericin-B (91%), Flucytosine (82%). Comparatively higher resistance in our study was seen in Fluconazole (12%). **Fan et al 2023** study also showed a high resistance rate of 16.5% for Fluconazole.

CONCLUSION

A total of 231 urine samples were received in the Microbiology Laboratory, the culture positivity rate was 37.67%. Out of 231 urine samples, bacteria were isolated from 63 urine samples and fungi from 24 urine samples. Out of 87 positive urine samples, Gram-positive bacteria were found to be 16; Gram-negative bacteria were found to be 47 and *Candida* species 24 in number. There was a female predominance, with 47 (54%) females and 40 (46%) males. Most of the isolates were found from people between the age of 40-60 years. Gram-negative bacteria were found to be the most pathogenic. *Escherichia coli* were found to be the main causative agents of UTI. Urinary Tract infection is one of the main leading microbial infections affecting people of all age groups and genders all around the world. In this study it was found that Gram-negative bacteria were the most common bacteria causing UTI out of which *Escherichia coli* was found to be the most common and important causative agent of UTI and *Candida* species were found to be one of the most common fungal growth causing UTI. Women were found to be more prone and affected by UTI than men. The infection mostly occurs in older people in comparison to younger people. The AST patterns of bacteria were found to be most resistant to Ciprofloxacin and most sensitive to Nitrofurantoin. The AST patterns of fungi were found to be most resistant to Fluconazole and most sensitive to Voriconazole, Amphotericin-B and Flucytosine.





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The increasing prevalence of UTI in India emphasizes the need for prior knowledge of causative agents of UTI and their antibiotic and anti-fungal susceptibility patterns as it is expected to improve the development of treatment, management and outcome. Antibiotics are mainly given for the treatment, such as Nitrofurantoin, Tetracycline, Fosfomycin etc. Although antibiotics are given for treatment some pathogens can become resistant to various antibiotics and can prevent the activity of the antibiotics. Recent studies shows that consumption of cranberry can help get rid of burning sensation or vaginitis caused by UTI and it could be one of the major important candidates to treat UTI. Preventive measures have to be taken to reduce the various risk factors. It can be mainly prevented by following a clean and hygienic lifestyle like drinking plenty amount of water, avoiding sexual intercourse with different multiple partners. If infected with UTI early treatment should be given to prevent further serious infections.

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Table 1-Distribution of Positive Specimens

Total No. of Specimens	Positive Specimens	Negative Specimens
231	87	144

Table 2- Distribution of causative organisms

Total No. of Positive specimen	Bacteria	Fungi
87	63	24

Table 3-Distribution of Gram-Positive, Gram-negative and Candida species

Total No. Of positive specimen	Gram-Positive Bacteria	Gram- Negative Bacteria	Candida species
87	16	47	24

Table 4-Distribution of bacteria on the basis of positive sample

Bacteria	Number of positive cultures
<i>Enterococcus faecium</i>	7
<i>Enterococcus avium</i>	1
<i>Enterococcus faecalis</i>	4
<i>Enterococcus gallinarum</i>	3
<i>Escherichia coli</i>	23
<i>Klebsiella pneumonia</i>	13
<i>Pseudomonas aeruginosa</i>	5
<i>Acinetobacter baumannii</i>	4
<i>Proteus mirabilis</i>	1
<i>Myroides spp</i>	1
<i>Staphylococcus hominis</i>	1





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Table 5- Distribution of patients on the basis of gender

Total No. of Positive Samples	Female	Male
87	47	40

Table 6- Age-wise distribution of UTI patients

Age Groups	20-30	30-40	40-50	50-60	60-70
No. Of Patients	15	16	21	19	16

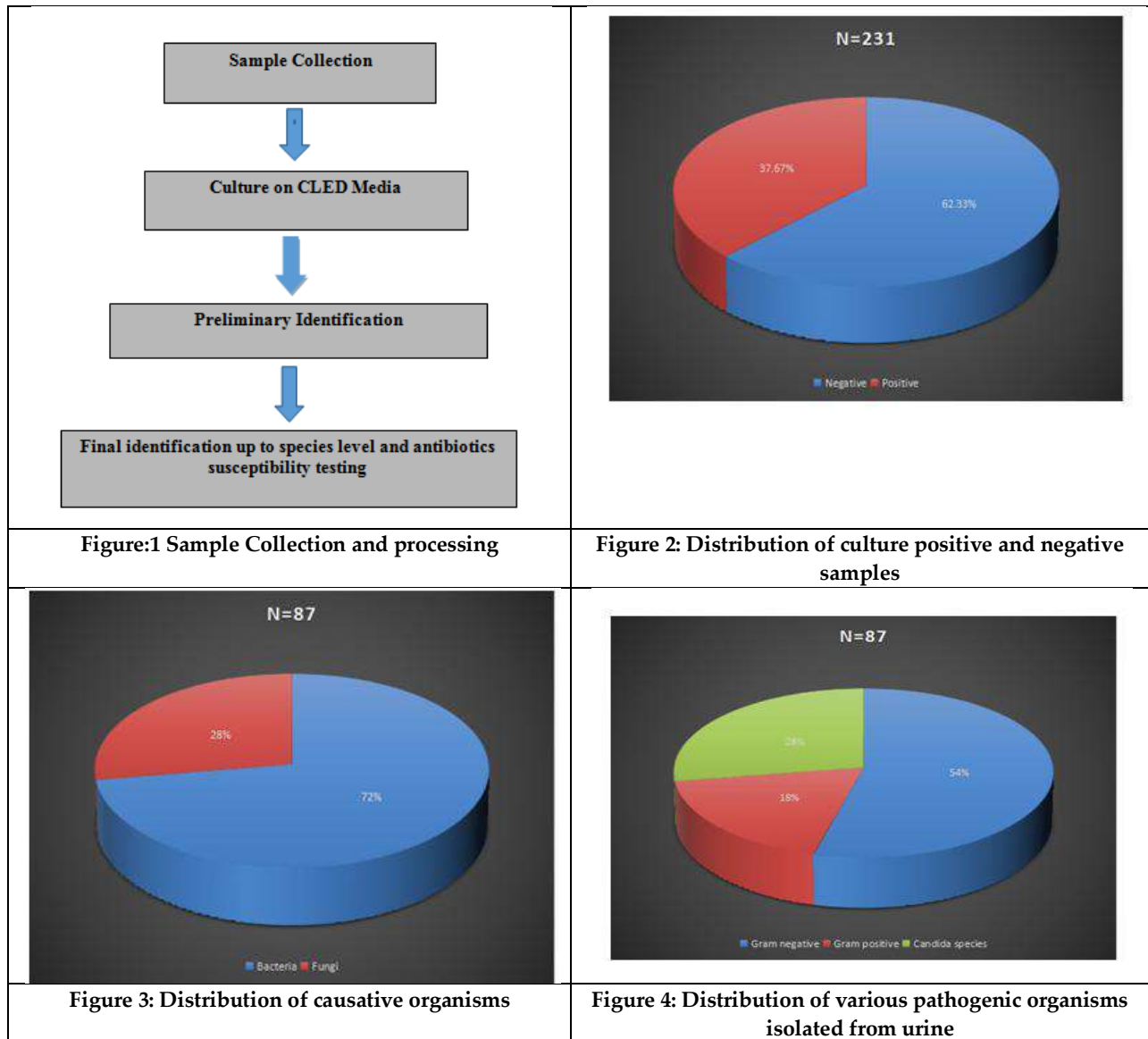
Table 7- Antibiotic Susceptibility Test (AST) of positive bacterial isolates

Antibiotics	Resistant	Sensitive
Nitrofurantoin (NIT)	16(25.3%)	30(47%)
Penicillin (P)	12(19%)	3(4.7%)
Tetracycline (T)	22(35%)	4(6.3%)
Ciprofloxacin (CIP)	48(76%)	4(6.3%)
Fosfomycin (FO)	2(3.1%)	22(35%)
Linezolid (LZ)	4(6.3%)	12(19%)
Vancomycin (VA)	1(1.5%)	9(14.2%)
Teicoplanin (TEL)	4(6.3%)	12(19%)
Ceftazidime (CAZ)	8(12%)	8(12%)
Cotrimoxazole (COT)	29(46%)	12(19%)
Piperacillin (PIT)	19(30%)	16(25.3%)
Meropenem (MRP)	18(28%)	25(39%)

Table 8- AST pattern of *Candida* isolates

Antifungal	Resistant	Intermediate	Sensitive
Fluconazole	3(12%)	1 (4%)	19(79%)
Voriconazole	2(8%)	0	22(91%)
Caspofungin	2(8%)	0	19(79%)
Micafungin	1(4%)	0	19(79%)
Amphotericin B	1(4%)	0	22(91%)
Flucytosine	1(4%)	0	22(91%)







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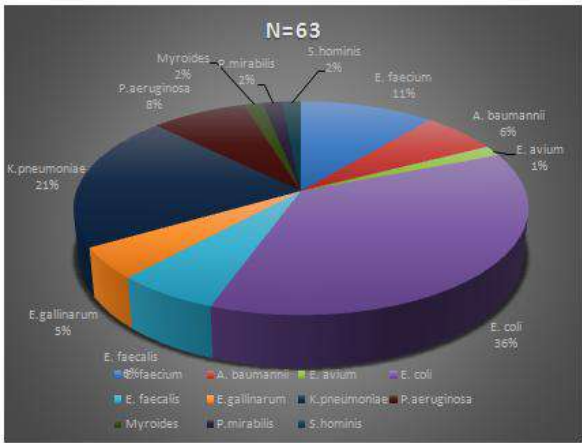


Figure 5: Distribution of Bacteria

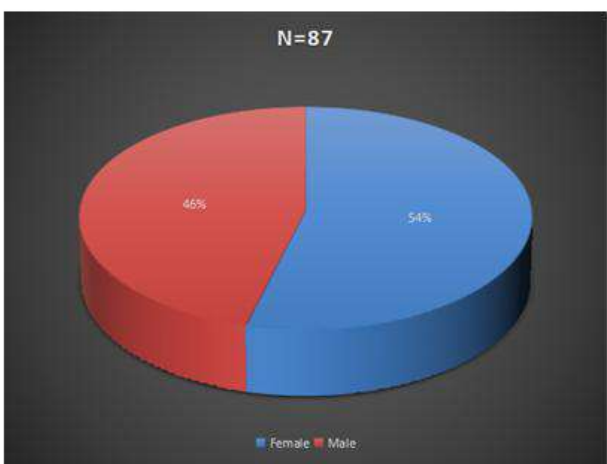


Figure 6: Distribution of patient on the basis of gender

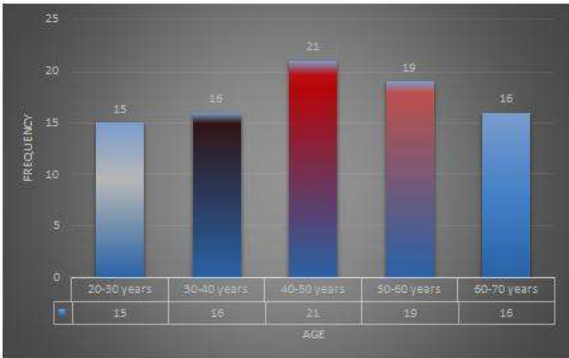


Figure 7: Age wise distribution of UTI patients





RESEARCH ARTICLE

Traditional Knowledge of Medicinal Plants Survey in Paruthivilai Village, Nagercoil, Kanyakumari District, Tamilnadu, India.

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ABSTRACT

India is rich medicinal plant heritage is being documented through an ethnobotanical study in Paruthivillai, Kanyakumari district, TamilNadu. Ethnobotanical data were gathered via interviews and semi-structured questionnaires from elderly traditional medicinal practitioners and local faith healers. A total of 62 plant species, representing 26 families, were documented, including 29 herbaceous species, 13 shrubs, 12 trees, and 8 climbing species. Plant species of Euphorbiaceae, Solanaceae, Fabaceae (6) is predominantly used, followed by Amaranthaceae (4), Malvaceae, Apocynaceae (3), Acanthaceae, Cucurbitaceae (2), Aeraceae, Rutaceae, Ashphodelaceae, Annonaceae, Meliaceae, Basellaceae (1) each etc., The traditional herbal healers quite frequently use leaves (36) followed by root (3), whole plant (8), fruit (10), flower (5), seed, and stem (2). The most common methods of drug preparation and application are the paste form (19), juice (25), decoction (11), powder (6), and gel (1). The diseases include skin diseases (9), asthma (7), fever, diabetes, dysentery (6), cough (4), jaundice, diarrhea (3), hair diseases, cold, anemia, chicken pox, rheumatism, (2), piles, kidney stone, scabies, arthritic, insect bite, hypertension, liver diseases, smallpox, ulcer (1) each. The indigenous community prefers these plants as home remedies against fever, rheumatism, headache, constipation, etc., simultaneously, effective measures should be taken to protect and preserve these significant plant species for future generations. I conclude traditional knowledge of medicinal plants is a valuable resource that deserves preservation and integration into modern healthcare.

Keywords: Traditional medicine, Paruthivilai, Medicinal uses.



**Santhiya and Mahesh**

INTRODUCTION

The plant parts used for the arrangement from asserting drug. Sum plants were found again used for those arrangements about cures (Kumar et al. 2019). Individuals living in emerging nations depend actually on customary medication for essential medical services (Singh 2002). India possesses an extraordinary wealth of plant resources, with a vast and varied flora that is among the most extensive in the world. It is assessed that north of 18,000 types of higher plants happen in various phytogeographical/biological locales of the country, in which around 33% are restoratively and monetarily significant species are recorded (Revathi et al. 2013). Plant drugs are generally utilized by the human populace either as people cures or straightforwardly from the systematized restorative frameworks for current homegrown arrangements. Native home-grown treatment is a piece of the way of life and a dominating method of treatment in most non-industrial nations. The traditional herbal remedies in question have proven to be remarkably effective and are both socially accepted and economically feasible, making them a valuable option. 33% of present-day drug arrangements have plant beginnings (Padal et al. 2021). Restorative plants are presently more engaged than at any other time since they have endless advantages to society for sure to humanity, particularly in the line of medication (Hussain et al. 2011). There is a pressing need to document these plant species before this valuable knowledge is lost forever, succumbing to the risk of extinction and cultural obsolescence. Furthermore, this study contributes to the conservation of these medicinal plants and provides foundational data for future phytochemical and pharmacological investigations (Gritto et al. 2015). Ethnobotany is drawing in experts from assorted scholastic foundations and interests. Ethnobotany might assume a significant part in getting manageable supplies, and it can likewise be useful in the quest for new restorative recipes that could be utilized to treat sicknesses for which no standard treatment has been accounted. Phytochemical research and ethnobotanical studies can unlock the medicinal potential of plant species by harnessing their chemical diversity (Kumar et al. 2022). In regards to medicinal utilization from claiming plant species, it varies around those communities, while a couple of plant needs the same use (Sukumaran et al. 2014). To document the indigenous uses of plants in healthcare among the local people of Paruthivillai in the Kanyakumari district. To document the botanical name, families, local names, habits, useful parts, diseases, and modes of use for each medicinal plant species.

STUDY AREA

Paruthivillai village located Under Nagercoil town has been chosen as the study area

MATERIALS AND METHODS

During the survey, a through approach was taken to ensure that no location was overlooked, as every area was considered potentially valuable for collecting plant species. Plant specimen were collected from their natural habitats during various seasons and at different reproductive stages. As part of the floristic documentation of the paruthivillai region, interviews were conducted with local people, traditional medicine men, and experts to gather information on the utilization value of plant species (Jain 1991). During each field trip and survey, efforts were made to collect both wild and cultivated plant species in their flowering, fruiting, and mature stages. Immediately after collection, specimens were numbered, labeled, and stored in polythene bags. Eac specimen was then identified and critically examined with the aid of written floras to ensure accurate classification (Gamble and Fisher, 1915-1935).

RESULT AND DISCUSSION

A total of 62 plant species from 26 families were indetified in the present study. Of these 29 were herbs, 13 were shrubs, 12 were trees and 8 were climbers. Plant species of Euphorbiaceae, Solanaceae, and Fabaceae (6) are predominantly used, followed by Amaranthaceae (4), Malvaceae, Apocynaceae (3), Acanthaceae, Cucurbitaceae (2), Asteraceae, Rutaceae, Ashphodelaceae, Annonaceae, Meliaceae, Basellaceae (1) each, etc., Traditional herbal healers quite frequently use leaves (39) followed by root (6), whole plant (5), fruit (12), flower (6), seed (2), stem (3), and bark



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(1). The most common methods of drug preparation and application are the paste form (19), juice (25), decoction (10), powder (7), and gel (1). The diseases include skin diseases (9), asthma (7), fever, diabetes, dysentery (6), cough (4), jaundice, diarrhea (3), hair diseases, cold, anemia, chicken pox, rheumatism, (2), piles, kidney stone, scabies, arthritic, insect bite, hypertension, liver diseases, smallpox, ulcer (1) each. The plant species in question possess medicinal properties capable of treating over 22 ailments. Interestingly, the number of plant species used to treat various across different regions. Moreover, it has been observed that a single plant species can be used to treat a single condition. This discovery contradicts existing research in the field. A total of 62 plant species have been identified in Kanyakumari district (Santhiya et al. 2021); 59 species (Kumaresubitha and Kolar, 2021); 44 plant species (Sheeja and Lohidas, 2020); 30 plants (Kingston et al. 2009); 25 plant species (Kingston et al. 2007); A total of 82 plant species (Loganathan and Selvam, 2018); A total of 35 angiosperm species, (Kannan and Jeeva, 2008); 55 plantspecies (Jhoncy et al. 2011); 54 plantspecies (Kensa et al. 2018); 106 plant species (Divya et al. 2013); 81 plant species (Vizhi and Lohidas, 2020); 48 medicinal plants (Pradeesh et al. 2020); 89 plant species (Jeeva and Femila, 2012); 138 plant species (Sukumaran et al. 2020); 29 plant species (Divya and Sukesh, 2023); 70 plantspecies (Prakash et al. 2024) are reported.

CONCLUSION

This study examines the medicinal value of plants in Paruthivillai village, Nagercoil Town Municipality. Taxonomically a total of 62 plant species belonging to 26 families were recorded. Of these 29 were herbs, 13 were shrubs, 12 were trees and 8 were climbers. Plant species of Euphorbiaceae, Solanaceae, Fabaceae (6) is predominantly used, followed by Amaranthaceae (4), Malvaceae, Apocynaceae (3), Acanthaceae, Cucurbitaceae (2), Aeraceae, Rutaceae, Ashphodelaceae, Annonaceae, Meliaceae, Basellaceae (1) each etc., The traditional herbal healers quite frequently use leaves (36) followed by root (3), whole plant (8), fruit (10), flower (5), seed, and stem (2). The most common methods of drug preparation and application are the paste form (19), juice (25), decoction (11), powder (6), and gel (1). The diseases include skin diseases (9), asthma (7), fever, diabetes, dysentery (6), cough (4), jaundice, diarrhea (3), hair diseases, cold, anemia, chicken pox, rheumatism, (2), piles, kidney stone, scabies, arthritic, insect bite, hypertension, liver diseases, smallpox, ulcer (1) each. Traditional knowledge of medicinal plants is a valuable treasure trove of natural remedies that have been passed down through generations, offering a sustainable and holistic approach to healthcare that warrants preservation, promotion, and integration into modern medicine to ensure a healthier future for all. Feel free to modify it to fit your specific needs or let me know if you'd like me to suggest any changes.

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Table-1 List of medicinal plant species collected from Paruthivilai village under Nagercoil Town

S.No	Botanical Name	Family	Local Name	Habit	Useful part	Diseases	Mode
1.	<i>Abutilon indicum</i> (L.) Sweet.	Malvaceae	Thuththi	Shrub	Leaf, flower	Piles	Powder
2.	<i>Acalypha indica</i> L.	Euphorbiaceae	Kuppaimeni	Herb	Whole plant	Skin diseases	Juice
3.	<i>Achyranthus aspera</i> L.	Amaranthaceae	Nayurivi	Herb	Whole plant	Skin diseases	Powder
4.	<i>Acorus calamus</i> L.	Aeraceae	Vasambu	Herb	Root	Cough	Decoction
5.	<i>Aegle marmelos</i> L. Correa.	Rutaceae	Vilvam	Tree	Fruits	Dysentery	Powder
6.	<i>Aerva lanata</i> (L.) Juss. ex. Schult.	Amaranthaceae	Pongal poo	Herb	Shoots	Kidney stone	Juice
7.	<i>Aloe vera</i> (L.) Burm. f.	Ashphodelaceae	Kattralai	Herb	Leaf	Hair diseases	Gel
8.	<i>Alternanthera sessilis</i> (L.) R. Br. ex Dc.	Amaranthaceae	Koduppaikeerai	Herb	Leaf	Hair diseases	Decoction
9.	<i>Amaranthus spinosus</i> L.	Amaranthaceae	Mulkerai	Herb	Leaf	Cold	Decoction
10.	<i>Andrographis paniculata</i> (Burm.f) Nees.	Acanthaceae	Nilavembu	Herb	Whole plant	Fever	Decoction
11.	<i>Annona squamosa</i> L.	Annonaceae	Seethapalm	Tree	Leaf, fruit	Anemia	Juice
12.	<i>Azadirachta indica</i> A. Juss.	Meliaceae	Vembu	Tree	Whole plant	Chicken pox	Paste
13.	<i>Basella alba</i> L.	Basellaceae	Pasalikkeerai	Climber	Leaf	Skin diseases	Decoction
14.	<i>Boerhaavia diffusa</i> L.	Nyctaginaceae	Mukkarattai	Herb	Whole plant	Jaundice	Powder
15.	<i>Calotropis gigantea</i> (L.) Dryand	Apocynaceae	Erukku	Shrub	Leaf	Skin diseases	Juice
16.	<i>Capsicum frutescens</i> L.	Solanaceae	Milagai	Herb	Root	Rheumatism	Decoction
17.	<i>Cardiospermum helicabum</i> L.	Sapindaceae	Mudankathan	Climber	Whole plant	Rheumatism	Decoction
18.	<i>Carica papaya</i> L.	Caricaceae	Pappaya	Tree	Fruit	Skin diseases	Juice
19.	<i>Catharanthus roseus</i> (L.) G. Don.	Apocynaceae	Nithyakalyani	Herb	Whole plant	Diabetes	Decoction
20.	<i>Centella asiatica</i> (L.) Urban	Apiaceae	Vallarai	Herb	Leaf	Skin diseases	Paste
21.	<i>Cissus quadrangularis</i> L.	Vitaceae	Pirandai	Climber	Stem	Asthma,	Paste





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						diabetes	
22.	<i>Clitoria ternatea</i> L.	Fabaceae	Sangupoo	Climber	Leaf	Diarrhea	Paste
23.	<i>Cocciniagrandis</i> (L.) Voigt.	Cucurbitaceae	Kovaikkai	Climber	Fruit, leaf	Scabies	Juice
24.	<i>Cocunucifera</i> L.	Arecaceae	Thennai	Tree	Fruit	Skin diseases	Paste
25.	<i>Coleus ambonicus</i> L. var.	Lamiaceae	Karpooravalli	Herb	Leaf	Cold	Decoction
26.	<i>Costusspiralis</i> L.	Costaceae	Insulin chedi	Herb	Leaf	Diabetes	Juice
27.	<i>Croton sparciflorus</i> L.	Euphorbiaceae	Rail poondur	Herb	Leaf	Diabetes	Juice
28.	<i>Curcuma longa</i> L.	Zingiberaceae	Manjal	Herb	Root	Skin diseases	Paste
29.	<i>Cynodondactylon</i> L. Pers.	Poaceae	Arugambul	Herb	Leaf	Dysentery	Juice
30.	<i>Datura metel</i> L.	Solanaceae	Oomaththai	Herb	Leaf	Arthritic	Paste
31.	<i>Eclipta prostrata</i> (L.)	Asteraceae	Karisalankanni	Herb	Leaf	Anemia	Paste
32.	<i>Euphorbia heterophylla</i> L.	Euphorbiaceae	Paalperukki	Herb	Leaf	Cough	Juice
33.	<i>Euphorbia hirta</i> L.	Euphorbiaceae	Amman pacharisi	Herb	Leaf, flower	Jaundice	Paste
34.	<i>Heliotropium indicum</i> L.	Boraginaceae	Thelkodu	Herb	Leaf	Insect bite	Juice
35.	<i>Hibiscus rosasinensis</i> L.	Malvaceae	Semparuththi	Shrub	Leaf, flower	Hypertension	Paste
36.	<i>Ixoracoccinea</i> L.	Rubiaceae	Idly poo	Shrub	Flower	Dysentery	Paste
37.	<i>Lablab purpureus</i> (L.) Sweet.	Fabaceae	Avarai	Climber	Whole plant	Fever	Juice
38.	<i>Lawsonia alba</i> L.	Lythraceae	Maruthaani	Shrub	Leaf	Hair diseases	Paste
39.	<i>Mimosa pudica</i> L.	Fabaceae	Thottaalvaadi	Herb	Leaf	Dysentery	Juice
40.	<i>Momordica charantia</i> L.	Cucurbitaceae	Paagarkai	Climber	Leaf	Chicken pox	Juice
41.	<i>Moringa oleifera</i> Lam.	Moringaceae	Murungai	Tree	Leaf	Asthma, diabetes	Juice
42.	<i>Murrayakoeiniji</i> L. Spreng.	Myrtaceae	Karuveppilai	Shrub	Leaf	Skin diseases	Paste
43.	<i>Musa paradisiaca</i> L.	Musaceae	Vaalai	Tree	Fruit	Dysentery	Juice
44.	<i>Nerium oleander</i> L.	Apocynaceae	Arali	Shrub	Stem	Asthma	Juice
45.	<i>Ocimum tenuiflorum</i> L.	Lamiaceae	Thulasi	Herb	Leaf	Asthma	Juice
46.	<i>Phyllanthus emblica</i> L.	Euphorbiaceae	Kaattunelli	Tree	Fruit	Jaundice	Paste
47.	<i>Phyllanthus niruri</i> L.	Phyllanthaceae	Keelanelli	Herb	Leaf	Liver diseases	Juice





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48.	<i>Phyllanthusreticulatus</i> L.	Phyllanthaceae	Inguchedi	Shrub	Leaf	Small pox	Paste
49.	<i>Piper betle</i> L.	Piperaceae	Vettrilai	Climber	Leaf	Cough, asthma	Paste
50.	<i>Psidiumguajava</i> L.	Myrtaceae	Koyya	Tree	Leaf	Diarrhea, dysentery	Decoction
51.	<i>Punicagranatum</i> L.	Lythraceae	Maathulai	Tree	Fruit	Diarrhea	Powder
52.	<i>Rhinacanthusnasutus</i> L.	Acanthaceae	Visapachchilai	Herb	Leaf	Skin diseases	Juice
53.	<i>Ricinuscommunis</i> L.	Euphorbiaceae	Aamanakku	Shrub	Seed	Diarrhetic	Paste
54.	<i>Sauropusandrogynus</i> (L.) Link.	Phyllanthaceae	Tavasimurungai	Shrub	Leaf	Diabetes	Juice
55.	<i>Sennaoccidentalis</i> (L.) Poiret.	Fabaceae	Sudalavarai	Shrub	Leaf	Fever	Paste
56.	<i>Sesbaniagrantiflora</i> L.	Fabaceae	Agaththi	Shrub	Flower	Fever	Juice
57.	<i>Sidacordifolia</i> L.	Malvaceae	Siththamutti	Tree	Leaf	Asthma	Juice
58.	<i>Solanumnigrum</i> L.	Solanaceae	Manathakkali	Herb	Leaf	Fever	Decoction
59.	<i>Solanumtorvums</i> W.	Solanaceae	Sundaikkai	Shrub	Seed	Ulcer	Juice
60.	<i>Solanumtrilobatum</i> L.	Solanaceae	Thoothuvalai	Herb	Leaf	Asthma	Juice
61.	<i>Solanumvirginianum</i> L.	Solanaceae	Kandankaththari	Herb	Fruit	Skin, cough	Paste
62.	<i>Tamarindusindica</i> L.	Fabaceae	Puliyamarm	Tree	Fruit	Fever	Powder



Figure 1: Map showing Paruthivilai study area Under Nagercoil

Figure:2 *Acalypha indica*L. *Aloe vera*(L.)Burm.f.



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Figure:3 *Tamarindus indica* L. *Achyranthes aspera* L.



Figure:4 *Cardiospermum halicacabum* L.
Catharanthus roseus L.





Case Study of Apasmara- Specific Effect of Panchgavya Ghrita with Conventional Treatment

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ABSTRACT

Epilepsy, known as *Apasmara* in Ayurveda, is a chronic neurological disorder characterized by recurrent seizures. This case study explores the therapeutic potential of *PanchgavyaGhrita*, a traditional Ayurvedic formulation, described in *Charak Samhita* in the management of *Apasmara*. The *PanchgavyaGhrita*, composed of five articles derived from cow, namely *Dugdha*(milk), *Dadhi*(curd), *Ghrita*(ghee), *Mutra* (urine), and *Shakrit*(dung), is renowned for its neuroprotective and anticonvulsant properties. This study is limited to one case of epilepsy who was treated with *PanchgavyaGhrita* over specific period. A 14-year-old male patient, with a history of frequent seizures since the age of five years was evaluated clinically by *Ayurveda* and advised to use *PanchgavyaGhrita* along with diet and lifestyle modifications. This application was not oral but specifically through *Matra basti* and *Nasya* with regular monitoring for seizure frequency, duration and intensity. The patients showed high levels of clinical response in seizure reduction as well as improved cognitive and motor skills. Neuro protective effect of *PanchgavyaGhrita*, due to its special and unique content seems to protect neuronal membrane stabilization thus improving synaptic transmission. The present case study serves an effort to showcase the immense potential of *PanchgavyaGhrita* in epilepsy along with appropriate adjuvant treatment which not only proves a new dimension for better management but keeps our traditional wisdom intact using modern therapeutic tools. More extensive studies are required to verify these results and identify the mechanisms involved.

Keywords: *Apasmara*, *PanchgavyaGhrita*, *Matra basti*, *Nasya*, Seizures.





INTRODUCTION

Smritapragamam prahurapasmaram [1] Epilepsy, known as *Apasmara* in *Ayurveda*, is a neurological disorder characterized by recurrent seizures. According to *Ayurvedic* texts, Due to mental causes such as *Chinta* (Anxiety) and *Shoka* (grief), the *Prakupita Vatadi doshas* (aggravated Vata and other doshas), residing in the *Manovahisrotas* of *Hridaya*, destroy the *Smaranshakti* (memory) and give rise to the disease of *Apasmara*. *Tamah pravesah*, *Samrambho* (Irritation), and loss of memory due to the aggravation of *doshas*. This severe disease is known as *Apasmara* [2]. *Smriti* is another name for the knowledge of past events, and the condition of its disassociation with above mentioned symptoms is termed as *Apasmara* [3]. *Apasmara* (epilepsy) is also a mental disorder, similar to *Unmada* (insanity), where no visible pathological changes are observed in the brain. From the perspective of the destruction of knowledge, it is like *Unmada*. However, in *Unmada*, there is a distortion of intellect, making it difficult for the patient to grasp the reality of what they see or hear. An insane person talks, but their speech is incoherent. Similarly, they eat but often do not have the proper sense of taste. The patient of *Apasmara* suddenly loses consciousness and cannot perform any action. In this way, there is a distortion of intellect in *Unmada*, whereas there is a complete destruction of perception (*sangya*) in *Apasmara*. The seizure in *Apasmara* is temporary and lasts for a short period, with the timing of the seizure often being predictable. This is not the case in *Unmada*, where the episodes are not temporary but rather have a more permanent nature [4]. This disease *Apasmara* occurs due to mental causes such as *Kama*, *Krodha*, *Bhaya*, *Lobha*, *Moha*, *Harsha*, *Shoka*, *Chinta*, *Udweaga*, as well as physical causes like head injury, meningitis, cerebral hemorrhage, and brain tumors. It arises when there is a deficiency of *Sattva Guna* and an increase in *Rajas* and *Tamas Gunas*. It is more commonly found in individuals with naturally weak minds. The aggravated *doshas* due to the aforementioned causes settle in the brain, sensory centers of the brain, and the nervous system, leading to the manifestation of *Apasmara* [5].

There are four types of *Apasmara* [6]

1. *Vataj*,
2. *Pittaj*,
3. *Kaphaj*,
4. *Sannipataj*

Nidanapanchaka of *Apasmara*

1. *Nidana*- The person whose *Vata* and other *doshas* wander in abnormal paths and move to the upper parts of the body, and the *doshas* have increased from their normal state, who consume *Ahita* and *Ashuchi Bhojana* (impure food); in such men, due to the increase of *Rajoguna* and *Tamoguna*, when *Sattvaguna* becomes weak and the *Hridaya* (heart) is surrounded by *Vata* and other *doshas*, and when the *Mana* becomes *Dushita* due to *Chinta*, *Kama*, *Bhaya*, *Krodha*, *Shoka*, *Udweaga*, etc., then the disease *Apasmara* occurs [7].
2. *Purvaroop*- *Hridkampa* (Palpitation of heart) and *Shunyata* (a feeling of emptiness in the heart), *Sweda pravritti* (sweating), *Chinta*, impairment of the functions of the *Mana* (mind) and *Indriyas*, and *Nidranasha* are the *Purvaroop* (prodromal symptoms) of *Apasmara* [8].
3. *Roopa*- The *Roopa* / *Lakshana* (symptoms) of four types of *Apasmara* are:
 - a. *Vataj Apasmara*- In this condition, the patient's body trembles, they clench their teeth, *Phen vaman* (dry froth comes out of their mouth), they take deep breaths, and see *Parush* (coarse), *Arun* (blackish red), and black forms.
 - b. *Pittaj Apasmara*- In this condition, yellow-colored *Phen* (froth) comes out of the patient's mouth, and the patient's body parts, face, and eyes turn yellow. When an episode occurs, the patient sees yellow or red forms. This patient experiences excessive thirst, a higher body temperature, perceives everything around them as if it is on fire.





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- c. *KaphajApasmara*- In this condition, white-colored froth comes out of the patient's mouth, and the patient's body parts, face, and eyes turn white. During an episode, the body becomes cold to the touch, the patient experiences *Hrishtaangata* (goosebumps), and a *Guruta*(sense of heaviness in body). During the episode, the patient sees everything in a white color, loses consciousness, and regains it after a long time.
- d. *SannipatajApasmara*- When the symptoms of *Vata*, *Pitta*, and *Kapha* are all observed together, are indicative to *Tridoshaja* (*Sannipataja*) type of *Apasmara*. This *Sannipataja Apasmara*is incurable. Moreover, if a man's *Dhatus* such as *Rasa*, *Rakta*, and others have become depleted, and this disease has become chronic, that *Apasmara*is also considered incurable.
- e. *Upshaya*- *Upshaya*of *Apasmararoga* depends on which *Dosha* is in domination. The diet and drugs which are opposite in nature to the predominant *Dosha*, prove to be *Upashaya*- beneficial for the cure of the disease.
- f. *Samprapti-Prakupita dosha* by *Visham Cheshta* will locate to the *Hridaya* and *Indriya* where *Rajas* and *Tamas* are already in *Prakupita*form. Once there, influenced by *Kama*, *Krodha*, *Bhaya*, *Lobha*, *Moha*, *Harsha*, *Shoka*, *Chinta*, *Udwega*etc., they suddenly attack the *Hridaya*and *Indriya* again, causing the person to lose his/her memory⁹.
- g. *Ayurved* provides multilevel treatment approach in such case that give relief in the complaints and provides the easiness in day-to-day work. In this case, *Apasmaraw*as diagnosed as the patient had symptoms like *BibhatsaCheshta*, *Smriti Naasha*, *Angamarda*, *Moha*, *Shirah Shula*, *Moorcha*. To describe the whole course of the treatment that was provided to the patient and thus get direction to treat such cases is the main aim of this Article.

Case Report

Chief Complaints

- Recurrent episodes of loss of consciousness, stiffening of the body and jerking of limbs (since 10 years)
- Sudden onset of strange smells.
- Drowsiness and Headache.
- Difficulty in recalling events before or after seizures.

Past History

- K/C/O: High grade fever in the age of 05yr.
- H/O: The patient had high fever for 3 days which caused him to have seizures.

Present Illness

- A 14-year-old male patient came in OPD with complaints of recurrent episodes of loss of consciousness, stiffening of the body and jerking of limbs, with Sudden onset of strange smells, Drowsiness and Headache. He also experienced difficulty in recalling events before or after seizures.
- In the age of 05 yr, he suffered from high grade fever for approximately 3 days and during this, he got seizures due to which he became unconscious and he regained consciousness after 12 hours., as per history given.
- From 2015, the patient undergone the treatment regimen that included AEDs (Anti-epileptic drugs), along with Multivitamins and some brain tonics.
- By 2020, despite taking this treatment continuously, he still had seizures twice a month, and an EEG test of the brain was performed in which changes in the pattern of brain waves was detected.
- Then the doctor has changed some medicines and continued the treatment.

Personal History

- Diet: Vegetarian, *Ruksha* (food have dry property/low fat diet), *Katuahara* (Spicy food), *Pishtanna* (Fine Flour-Fast Food)
- Appetite: Low
- Sleep: Disturbed due to headache
- Bowel: Irregular -occasional constipation





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- Micturition: Abnormal
- Addiction: No specific addiction
- Blood Group: B+ve

Examination

General Examination

- The general condition of the patient was fair.
- No pallor seen.
- Pulse-78/min
- BP: 130/90 mm of hg
- CVS: S1, S2 Normal
- Ht: 150cm
- Weight: 42Kg
- RS: Auscultation of the lungs reveals clear breath sounds in both the anterior and posterior regions.
- P/A: The abdomen is soft and non-tender on palpation.

Clinical Examination

EEG -in sleeping condition, in which changes in the pattern of brain detected.

Ashtavidha Pariksha

- Nadi (Pulse)- Vata Pitta
- Mala (Bowel habits)- Irregular
- Mutra (Urine)- NAD
- Jihva (Tongue)- Mild coated
- Shabda (Voice of patient)- NAD
- Sparsha (Touch)- Sama shitoshna
- Drik (Eye & Vision)- NAD
- Akriti (samhanan)- Madhyama (Medium)

Investigation

SampratiGhataka

Agni: Jatharagni, Rasagni

Srotas: Manovahsrotas

Dosha: Tridosha (Vata, Pitta, Kapha), Rajas, Tamas

Dushya: Ras, Rakta, Manas

Samutthana: Vata Pittakara Ahar

Vyaktasthana: Gyanendriya, Karmendriya

Diagnosis

The patient was already diagnosed with Epilepsy in 2014 which is compared with *Apasmara* in *Ayurved* on the basis of the symptoms, described by the patient at the time of consultation.

Treatment Plan

Upon considering the seriousness of this illness, it is essential to assess the condition of the disease and the patient and validate the effectiveness of a well-established medication like '*PanchagavyaGhrita*' through clinical trial. According to the line of the treatment of *Apasmara*, *PrabodhanoftheHridaya*, *Srotas*, and *Manas*, *Avrit* by these *PrakupitaVata* and other *doshas*, the physician should initially treat the patient with *Tikshna Vaman*, *Nasya*, etc. procedures[10]. As per the symptoms it is understood that the *Vata dosha* is vitiated in patient so, to counter act it, the *basti* therapy was planned.

Purva Karma





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Pradhana Karma

Pratimarsha Nasya-

Shiva Kshara Pachana Churna- 10 gms- after ½ hr. of meal- twice a day.

Dietary Regimen

- Provide *Laghu Ahara* (a light, easily digestible diet) such as *Peyaa* (rice gruel), boiled vegetables, and moong dal soup.
- Avoid foods that aggravate Vata, such as dry, cold, and raw foods.

Lifestyle Recommendations:

- Encourage the patient to follow a Proper *Dincharya* and sleep schedule.
- Meditation, *Pranayama* and gentle yogic exercise for mental relaxation and peaceful surroundings.

Follow-Up

To Monitor the patient's response to the treatment. Follow up after 15 Days. Patient came for follow up on Date 11/03/2024- In this duration no any episode of *Apasmara* occurred in patient. He feels relief in Headache and Drowsiness also. He feels fresh and more focused. So, we continue only the *Nasya* of *Panchagavya Ghrita* for next 15 days. After 15 days patient came for follow up on Date 25/03/2024- In this duration no any episode of *Apasmara* occurred in patient. He got complete relief in Headache and Drowsiness also. He feels fresh and more focused. No onset of strange smells.

Observation

A comparison between the results of EEG - in sleeping condition conducted after treatment, in which no changes in the pattern of brain detected. So, we Continue the *Nasya Karma* for next 2 months.

DISCUSSION

In the present case, the patient reported a reduction of 60% in signs and symptoms within first 15 days treatment. As per the chronic condition of the patient and the recommendation in the classics for treating *Apasmara*, the *Panchgavya Ghrita* was incorporated into the treatment plan with appropriate modifications. There was significant improvement in the episodes of *Apasmara*, seizures and headache with reduced severity of the all symptoms.

Shodhana Chikitsa

Snehana: As a part of the initial treatment protocol, *Snehana Karma* was administered before *Basti Karma*.

Swedana

After *Snehana*, *Swedana* is done to dissolve the *Prakupita Doshas*. So *Avgahana Swedana* was performed by considering the *Aayu* and *Bala* of patient.

Basti Karma

Basti is considered as *Ardhachikitsa*. In this case as *Apasmara* has the good amount of involvement of *Vata Dosh*, *Basti* produced a significant result. By applying *Matra Basti*, the timing in the interval between seizures took a significant change and symptoms like headache and drowsiness etc, got completely cured.

Pratimarsha Nasya

Nose is considered as the gateway towards the head. By applying *Nasya*, the patient gets significant relief in symptoms like headache etc in the first week itself. That really helps the patient to come to follow up. And by relieving other symptoms, the focus easily shifts into main disease and the *Nasya Karma* helps in bringing back the *Smaranashakti* (memory).





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CONCLUSION

In above said case, the patient showed more than expectation improvement through the combined treatment of *Panchakarma* therapy *Basti* and *Nasya*. Despite the usual oral use of *PanchgavyaGhrita* the incorporation of *Basti* and *Pratimarsha Nasya* of *PanchgavyaGhrita* proved highly beneficial. As patient has History of *Vata* dominant *Apasmara* the treatment resulted in Headache, Drowsiness and mainly in seizures leading to improvement in *Smaranshakti*(memory)and a better-quality life. This case highlights the efficacy of a well-adapted and holistic approach to treating *Apasmara*.

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Table 1: Demographic Data of the Patient

Demographic data (Table No. 1)		
Name		XYZ
Age & Sex		14/ Male
OPD	Number	22
	Visit Date	20/02/2024
Occupation		Student

Table 2.The comparative blood investigations reports

Blood Investigations (Table No. 3)	20/02/2024
Hb (mg/dl)	12.3
RBC (million/mm ³)	4.0
WBC (mm ³)	7500
Platelets (mm ³)	305000





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Table :3 Purva Karma

Snehana	<i>Sarvanga Abhyanga with Dashmoola Taila</i>	22/02/2024-26/02/2024
Swedana	<i>Avagaahana with DashmoolaSadhita Jala</i>	22/02/2024-26/02/2024

Table 4: Basti karma

Matra Basti	<i>PanchagavyaGhrita- 30 gms</i>	22/02/2024-26/02/2024 (after Snehana- Swedan)
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Table 5: Pratimarsha Nasya

Pratimarsha Nasya	<i>PanchagavyaGhrita- 2 drops- twice a day</i>	Daily
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A Breakthrough in Treating Tuberculosis - BPaLM Regimen

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ABSTRACT

Tuberculosis (TB) is an infectious disease that most often affects the lungs and is caused by a type of bacteria *Mycobacterium tuberculosis*. Infected people spread TB through the air when they cough, sneeze, or spit. An estimated 10.6 million people effected with tuberculosis and 1.3 million people died from TB in 2023 as per WHO reports. India has incidence rate of 192 cases per 100,000 of population and in 2023, India accounted for 2.5million TB cases registered. Although there was treatment for TB like first line and second line drugs but the usage is for prolonged time and it is not assured that it can completely kill the tuberculosis bacteria. Due to that the new novel drug treatment was introduced that is called as BPaLM therapy. It stands for Bedaquiline, Pretomanid, Linezolid and Moxifloxacin. This combination therapy is part of newer treatments being developed to address multidrug resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB). It has been a promising alternative due to shorter treatment durations and improved outcomes. The drugs were chosen because they target different critical bacterial functions such as energy production, protein synthesis, cell wall synthesis, and DNA replication-providing a strong and multi-prolonged attack on *Mycobacterium tuberculosis*. This new treatment duration is very short that is 6Months as compared to older therapy of 18-24 months. The CDSCO in India approved this therapy on 6th October 2024.

Keywords: Tuberculosis, MDR-TB, BPaLM, Bedaquiline, Pretomanid, Linezolid, Moxifloxacin, ATP Synthase, Peptidyl transferase, DNA topoisomerase & DNA Gyrase.



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INTRODUCTION

Tuberculosis (TB) is caused by a type of bacteria known as *Mycobacterium tuberculosis* which is responsible for the infectious disease, it generally affects the lungs. People who are infected with cough, sneeze, or spit, it spreads through the air [1]. tuberculosis can be avoided or treated. It is estimated that TB bacteria has infected 25% of the world's population [2]. Approximately 5–10 percent of TB infected individuals will eventually experience symptoms and develop TB disease. The disease cannot be transmitted by those who are infected. Antibiotics are usually used to treat tuberculosis, which can be fatal without treatment [1]. The Bacille Calmette-Guerin (BCG) vaccine is given to babies and young children in some countries to prevent tuberculosis. The vaccine does not prevent TB other than lungs [2]. A sum of 1.3 million individuals died from TB in 2022 (167000 individuals with HIV). After COVID-19, TB is the leading infectious disease that kills more people worldwide than HIV and AIDS [3]. TB affects people of all ages and nationalities.

Tuberculosis status in India

Tuberculosis is one of India's major public health issues. India has the largest tuberculosis epidemic in the world, according to WHO estimates. In 2020, India will account for 26% of all incident TB cases worldwide [2]. The incidence rate in India is 192 cases per 100,000 people. India was responsible for 34% of all TB deaths among HIV-positive and HIV-negative individuals and 38% of all deaths worldwide among HIV-negative individuals. Furthermore, many research studies have investigated the effects and consequences of TDR-TB, particularly in India, where social and economic development is still in progress [3]. In India, tuberculosis is responsible for the death of every third AIDS patient. In 2020, India accounted for 24% of the global gap between the estimated incidence of TB and the number of people newly diagnosed with TB and reported. The ministry reiterated their commitment to eliminating tuberculosis in the country by 2025. On December 30, 2019, the Union Government changed the name of the Revised National Tuberculosis Control Program (RNTCP) to National Tuberculosis Elimination Program (NTEP). This was performed as part of its efforts to eradicate tuberculosis [4].

Treatment of TB with novel drugs in different nations:

A brief overview of countries with BPALM or related regimens, along with timelines, are as follows:

- i. South Africa (2018): One of the first nations to use Pretomanid -based regimens in clinical trials to combat XDR-TB was South Africa. After the WHO approved BPALM, it became easier to access.
- ii. India (2021): To address its significant drug-resistant TB, India has participated in BPAL and BPALM regimen research and clinical trials. India's Central Drugs Standard Control Organization granted Pretomanid approval. The World Health Organization (WHO) approved pretomanid-containing regimens in 2019, leading the WHO to roll out these regimens more broadly across several countries actively involved in TB research and treatment. As more nations adopt these more recent regimens in response to their requirements for public health and regulatory approval, access continues to rise [4].
- iii. United States (2019): The treatment of extensively drug-resistant tuberculosis (XDR-TB) with Pretomanid, Bedaquiline, and Linezolid received approval from the Food and Drug Administration (FDA). MDR-TB and XDR-TB are both treated with this regimen. In the United States, clinical trials have performed for BPALM, including Moxifloxacin, but BPAL was the first significant step [5].
- iv. France (2019): By the WHO recommendation in 2019, the use of Pretomanid-containing regimens was approved in France through the European Medicines Agency (EMA). For MDR-TB patients, French healthcare authorities have participated in clinical trials and special access programs, and BPALM has been included in these trials for cases of drug-resistant TB [5].
- v. United Kingdom (2021): UK's National Health Service (NHS) and Public Health England began using Pretomanid-containing regimens to treat MDR-TB in 2021. Pretomanid and the BPALM regimen have been approved, but their rollout has been limited, with MDR-TB and XDR-TB cases serving as the primary focus [4].





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- vi. Russia (2020): BPALM regimen was part of national programs to combat drug-resistant TB in Russia, which had one of the highest rates of MDR-TB and XDR-TB in Europe. Early use of the regimen was prompted by Russia's participation in the WHO-coordinated clinical trials and its need for effective MDR-TB treatments [5].

Types of Tuberculosis

- i) **Pulmonary Tuberculosis:** Common symptoms of pulmonary tuberculosis include a cough and abnormal chest radiographs. They might spread disease among people and causes most cases registered for Pulmonary TB [6].
- ii) **Extrapulmonary Tuberculosis:** This affects the lungs and causes extrapulmonary tuberculosis, which affects the pleura, lymph nodes, brain, kidneys, and bones and joints. TB can affect any part of the body. Most of the time, people with extrapulmonary TB disease don't get sick unless they have a disease of the lungs in addition to other diseases of the lungs or laryngeal disease, an extrapulmonary condition or an extrapulmonary disease with an open abscess or lesion that has a high concentration of organisms, especially if the drainage fluid from the abscess or lesion is aerosolized or if it drains a lot. Both pulmonary and extrapulmonary TB are frequently present in HIV-positive individuals [5].
- iii) **Miliary TB disease:** Miliary TB disease is a rare but serious condition caused by tubercle bacilli spreading to all parts of the body, where they grow and cause disease in multiple locations. Miliary refers to the appearance of millet seeds dispersed throughout the lung on a radiograph. It can affect anyone, but infants and children younger than 5 years old and people with immune problems are more likely to be affected. Military tuberculosis can be found in a single organ (such as the brain), multiple organs, or the entire body. If left untreated, it is fatal [4][5]. Meningeal involvement may occur in up to 25% of military TB patients [6].
- iv) **TB Meningitis:** The tuberculosis causes the Meningitis of the brain and the spinal cord. Imaging studies frequently reveal it at the base of the brain. Meningitis patients frequently have miliary TB disease and chest radiograph abnormalities that are consistent with previous or current TB disease [4].
- v) **Drug-Resistant TB diseases:** Drug-Resistant TB disease is affected by *Mycobacterium tuberculosis* organic entities that are impervious to the medications ordinarily used to treat the sickness [3]. Drug-resistant tuberculosis is as infectious as drug-susceptible tuberculosis and is transmitted in the same manner. However, prolonged periods of infectiousness or a lack of recognition of drug resistance may facilitate increased transmission and the development of drug resistance [4]. TB is caused by a *Mycobacterium tuberculosis* strains that are *in vitro* resistant to rifampicin and isoniazid is MDR (multidrug-resistant) TB. TB brought about by types of *M tuberculosis* that are safe *in vitro* to isoniazid, rifampicin and something like one injectable specialist (i.e., amikacin, kanamycin or capreomycin) and any of the fluoroquinolones [6].
 - a) **Mono-resistant TB:** This is a type of TB caused by strains of *M. tuberculosis* that are resistant to just one first-line anti-TB drug.
 - b) **Poly-resistant TB:** TB caused by strains of *M. tuberculosis* that are resistant to more than one first-line drug, but not isoniazid and rifampicin together
 - c) **Multidrug resistance TB (MDR-TB):** It is a form of TB that is resistant to either one of the most powerful first line drugs such as either isoniazid or rifampicin.
 - d) **Extensively drug-resistant TB (XDR-TB):** It is most rare and severe case where all effective drugs to treat *mycobacterial tuberculosis* is resistant

vi). Drug-susceptible Tuberculosis: DS-TB is a case where a person is infected with TB bacteria that are to all first line anti-TB drugs. It means that all of the first line TB drugs will be effective as long as they are taken properly and regularly. This type of TB has the best prognosis and the shortest treatment duration. Patients diagnosed with TB are considered to be DS-TB the case, till such time they are detected with resistance to any anti-TB drugs.

Treatment of TB

Treatment of MDR-TB is difficult due to the majority of weak and toxic second-line TB medications. The majority of these drugs were developed decades ago but are rarely utilized due to their adverse effects. MDR-TB treatment typically takes 18–24 months due to the second-line drugs' weak sterilizing properties [4]. Cure rates range from 60 to 80 percent in the most effective treatment programs that aggressively manage side effects and address socio-economic barriers [5]. However, the cure rate for MDR-TB is significantly lower worldwide. The World Health

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Organization said in 2013 that only 48% of MDR-TB patients were cured. Even lower is the global cure rate for XDR-TB: according to WHO 2013 Only 20% are cured, and 44% died [6]. The primary first-line anti-TB medications are isoniazid, rifampicin, pyrazinamide, ethambutol, and streptomycin. Anti-TB medications have traditionally been classified as first-line and second-line medications [7]. We use the WHO system for this review, which divides the drugs into five groups based on efficacy, use experience, safety, and drug class. The safety profile and efficacy of drugs in the same group are not always the same, and they do not always belong to the same drug class [8]. The below table 1&2 describes about the classes of anti-tubercular drugs based on Minimum inhibitory concentration (MIC), efficacy, drug class and their experience of use.

TREATMENT OF TB THROUGH MDR TB & XDR TB

The BPaLM regimen combines four drugs with distinct but complementary mechanisms of action to target energy production, cell wall integrity, protein synthesis, and DNA replication of *Mycobacterium tuberculosis*. It is highly effective in treating drug-resistant tuberculosis. These mechanisms are complement to one another as following: The depletion of energy caused by Bedaquiline makes it more difficult for the bacteria to resist the effects of the other drugs. By making the bacterial cells more permeable, Pretomanid makes it easier for Linezolid and Moxifloxacin to enter and function more effectively [9]. Linezolid and moxifloxacin impair the bacterium's ability to repair the damage brought on by energy loss and cell wall disruption by interfering with fundamental processes like protein synthesis and DNA replication.

Bedaquiline (B)

Starving a Bacteria, Bedaquiline targets the ATP synthase enzyme in TB bacteria, this ATP synthase is responsible for energy production through the generation of ATP. Without energy, the bacteria cannot survive, especially in actively replicating states [9]. Bedaquiline inhibits bacteria by reducing their energy, which leaves them more susceptible to the effects of other medications that target essential functions including DNA replication, protein synthesis, and cell wall formation [8][10].

Pretomanid(Pa)

Disrupting the Cell Wall and Killing Dormant Bacteria, Pretomanid disrupts mycolic acid synthesis, which is essential for building and maintaining the thick and waxy cell wall that protects TB bacteria. It also generates reactive nitrogen species under low-oxygen (anaerobic) conditions, effectively killing dormant TB bacteria [9]. As Pretomanid disrupts the cell wall, the bacteria are exposed and more vulnerable to the energy depleting effects of Bedaquiline as well as the impacts of Linezolid and Moxifloxacin on DNA and protein activities. Additionally, Pretomanid ensures complete bacterial death by killing dormant or slow-growing bacteria that other medication.

Linezolid(L)

Inhibition of Protein Synthesis, Linezolid binds to the 50S ribosomal subunit, blocking bacterial protein synthesis. Without functional proteins, the bacteria cannot maintain essential cellular processes or reproduce [10]. The combination of the other medications increases the effectiveness of linezolid's suppression of protein synthesis. Pretomanid's rupture of the cell wall increases Linezolid's capacity to enter bacterial cells, while Bedaquiline's energy depletion makes it more difficult for the bacteria to adapt or survive [11]. Linezolid inhibits the bacterial repair of the damage caused by the other medications by inhibiting the synthesis of proteins.

Moxifloxacin (M)

Preventing DNA Replication as Moxifloxacin is a fluoroquinolone that targets DNA gyrase and topoisomerase IV, enzymes necessary for DNA replication and repair [8]. This prevents the bacteria from copying their DNA, effectively inhibiting their reproduction and ability to fix any DNA damage. Bedaquiline which deprives the bacteria of energy and Linezolid which inhibits protein synthesis work in tandem with Moxifloxacin's capacity to inhibit DNA replication. When combined these processes stop the bacteria from growing or repairing themselves which results in the death of the organism [9][10].





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The Benefits of novel combination BP aLM

- i) The bacteria have a much lower chance of developing resistance if they target multiple pathways including energy, the cell wall, protein, and DNA. The other drugs target distinct essential systems so even if the bacteria were to adapt to one they would not be effective [11].
- ii) Dormant TB bacteria which are typically more difficult to eradicate with standard antibiotics are particularly well-suited to Pretomanid's effectiveness. This guarantees that the treatment works on all bacterial populations not just those that are actively reproducing [10].
- iii) In contrast to older TB regimens which can take anywhere from 18 to 24 months the potent combination enables a shorter treatment duration of typically 6 months.
- iv) The BP aLM regimen treatment acts effectively by developing and lethargic microorganisms are destroyed there is no chance for the microscopic organisms to continue and reactivate later [11].

BEDAQUILINE

Mechanism of action

Bedaquiline is an anti-mycobacterial diarylquinoline that inhibits *M. tuberculosis* energy-generating enzyme, ATP (adenosine 5'-triphosphate) synthase, by binding to subunits of the enzyme [10][11]. From bacteria to mammals, the F₁F_o ATP synthase (M.W. 600 kDa for the monomer) is highly conserved. The ATP synthase contains a reactant F₁ segment, a fringe tail or stator, and the layer installed, F_o district. F_o has a proton turbine made up of a ring of c-subunits—eight in mammals, ten in yeast, 14 in the chloroplast, and a variety of stoichiometries in bacteria—and an a-subunit that serves as the conduits for proton entry and exit. The proton flow provides the energy for the phosphorylation of ADP in the active site of F₁, and the c-ring, which is connected to the central stalk of F₁, rotates driven by the movement of protons down the potential gradient from the cell's cytosol to the mitochondrial matrix [12]. By binding to F_o of the ATP synthase Bedaquiline inhibits *Mycobacterium tuberculosis* ATP synthesis. According to biochemical and x-ray crystallographic studies, BDQ binds to the *Mycobacterium phlei* 23 c-ring. While BDQ is a potent inhibitor of the mycobacterial ATP synthase, studies have shown that it has little effect on the human enzyme. The studies decided to independently examine the effect of BDQ on the mitochondrial ATP synthase because of the high rate of death following the administration of Sirturo. The studies present biochemical evidence that BDQ inhibits mitochondrial ATP synthase in yeast and humans. The mammalian enzyme's highly conserved BDQ binding site on yeast mitochondrial F_o is identified by cryo-EM [13]. A model of the binding pose is then created using simulations of molecular dynamics. These findings suggest that BDQ's inhibition of the human ATP synthase may be a factor in the high mortality rate following administration, and it is likely that BDQ derivatives can be more selective toward the mycobacterial enzyme. The human ATP synthase is inhibited by Bedaquiline [12].

One or more BDQ molecules can bind to the c-ring's membrane-exposed ion-binding sites and approach the ATP synthase, depending on the concentration of BDQ. Whether BDQ would likewise bind to the a-subunit or bind some place at or inside the a/c-ring point of interaction can't be decided with sureness with a presently accessible information. However, the fact that no drug-resistant a-subunit mutants have yet been identified contrasts with resistant mutants with c-subunit-exclusive mutations and suggests that this is not a possibility. Therefore, Phe69 alters its conformation as the drug approaches the c-ring to prevent steric clashes and provides BDQ with a hydrophobic platform. BDQ itself has the ability to alter its conformation and, as a result, aids in the development of numerous distinct molecular interactions, such as the ionic intermolecular H-bond between the DMA group and Glu65. Similar to the ion-coordinating glutamate-arginine interaction in the adjacent stator subunit a, this interaction is strictly conserved and essential to function [12]. As a result, when a c-subunit crosses the rotor-stator interface, the Glu65-DMA conformation appears to mimic a transition state during the ion translocation process, allowing BDQ to capture this crucial state in the F_o-motor mechanism. The bulky BDQ molecule would be energetically highly unfavourable to bind or pass this barrier because of the tight and partially hydrophilic rotor-stator region found in bacterial ATP synthases effectively preventing c-ring rotation and consequently an ion exchange in F_o. The complete halt of coupled ATP synthesis that follows has a significant effect on the general bioenergetic metabolism [13][14]. Tuberculosis and ultimately kills mycobacterial survival. According to this proposed mechanism, biochemical data





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support the conclusion that binding just one BDQ molecule to each ATP synthase is sufficient to completely prevent ATP synthesis [14].

Uses

Bedaquiline is used with three other medications to treat multi drug-resistant tuberculosis this treats only bacterial infections[12][13].

Side effects

Nausea, joint pains, headaches, and chest pain, liver dysfunction, and increased risk of death, coughing up blood, chest pain, fast/irregular heartbeat, severe dizziness fainting [14].

LINEZOLID

Chemical Formula: C₁₆H₂₀FN₃O₄

Mechanism of action

Linezolid inhibits bacterial protein translation by binding to a site on the 50S subunit of 23S ribosomal RNA and preventing the formation of a functional 70S initiation complex, which is necessary for bacterial reproduction, thus inhibiting bacterial division. At first, it was thought that linezolid worked by binding to the 23S rRNA of the 50S ribosomal subunit, close to the peptidyl transferase centre (PTC) of the would-be ribosome, before the 70S initiation complex was formed. The antibiotic would inhibit the ability of the 50S ribosomal subunit to bind to the 30S subunit upon binding to the subunit. This would prevent the 70S initiation complex, which is made up of the 50S and 30S subunits obstruct the early stages of protein synthesis. In contrast to other antibiotics that inhibit the elongation phase of protein synthesis, this proposed mechanism of action is unique [15]. However, subsequent research and crystallography analyses suggested that the more likely binding site for linezolid to the ribosome's PTC. Additionally, when alanine is the ultimate amino acid in the nascent chain, it was discovered that linezolid binds more effectively to the A site of the ribosome. This is because the alanine residue would fit into a hydrophobic pocket in the structure of the linezolid, allowing it to bind to the ribosome and prevent the PTC from interfering with the formation of the peptide bond between the A and E sites of the tRNA depicts the reported mechanisms of linezolid resistance in mycobacteria [16]. The tRNA loss-of-function mutations are not depicted, due to a lack of information regarding the proposed mechanism associated with these mutations, the tRNA loss-of-function mutations are not depicted. a) Ribosomal changes (mutations in either the L3 ribosomal protein or the 23S rRNA) that change the rRNA's conformation at the linezolid binding site and prevent it from binding to the peptidyl transferase centre (PTC) b) Mutations that result in the overexpression of efflux pumps that remove linezolid molecules from within cells [17]. c) The mutation in FadD32 that affects how mycolic acid is made. The increased hydrophobicity of the mycobacterial cell wall and decreased intake of linezolid, a drug that is hydrophilic, could result from this mutation's increased production of mycolic acids. The linezolid's decreased activity is indicated by red crosses.

Mutations in a 23S ribosomal RNA (rrl)

The 23S ribosomal RNA is a crucial part of the ribosome and makes up a significant portion of the 50S ribosomal subunit. It is one of the most frequently targeted binding sites for ribosome-targeting antibiotics like chloramphenicol and forms the PTC. It is centered around DomainV of the rRNA. As a result, linezolid-resistant mycobacteria also frequently exhibit 23S rRNA mutations. Linezolid resistance-conferring mutations in the 23S rRNA have been found to be mostly concentrated in its two domains, Domain V and Domain VI. Mutations in the rrl gene, which encodes the 23S rRNA, have been observed in numerous clinical isolates, particularly g2814t, which has been reported in numerous locations as far apart as India, South Africa, and Russia. Since this domain forms the PTC of the ribosome, a site where linezolid binds, mutations in Domain V should be expected to have an effect on linezolid resistance. However, the mechanism by which linezolid resistance is conferred on mycobacteria by mutations in Domain VI is poorly understood. Mutations may alter the interactions between the domain and the L6 ribosomal protein, an important protein close to the PTC's binding site, as one possible mechanism [15][17]. In addition, cross-linkages between the helices of Domain VI, the L6 protein, and Domain V are essential for preserving the ribosome's





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secondary structure. As a result, linezolid resistance may be conferred by mutations in Domain VI altering the structure of the rRNA. To better comprehend the connection between linezolid resistance and these ribosomal structures, additional research is required [15][16].

Uses

Linezolid is used to treat various infections such as including pneumonia and infections of the skin [16].

Side effects

Decreased platelets, white blood cell counts, headache, haemoglobin levels, diarrhoea, elevated pancreatic enzymes, elevated liver function tests, and neuropathy [15][17].

PRETOMANID:

Chemical formula: C₁₄H₁₂F₃N₃O₅

Mechanism of action

Pretomanid is a prodrug that is metabolically activated by a nitroreductase enzyme known as Ddn. This causes Pretomanid to produce the number of active metabolites that are responsible for its other therapeutic effects, particularly its ability to increase nitric oxide levels. Pretomanid is activated by the nitroreductase enzyme, which requires the reduced cofactor F420 and is dependent on deazaflavin. The enzyme glucose-6-phosphate dehydrogenase is used to reduce F420[18]. The metabolites, which include a des-nitro derivative, are created when the imidazole ring of the Pretomanid is reduced at the C-3 position. It has been reported that bactericidal activity against anaerobes is associated with a shorter duration of antibiotic treatment because the formation of this derivative results in increased levels of nitric oxide, which in turn causes bactericidal activities under anaerobic conditions through its action as a bacterial respiratory poison [19]. Pretomanid is a Nitroimidazooxazine medication that prevents mycolic acid from being made by preventing the production of bacterial cell walls, it kills *M. tuberculosis* that is actively reproducing, allowing for increased drug penetration into the bacterial cell[20]. Pretomanid is a prodrug that is metabolized to highly reactive nitro compounds like nitric oxide by the bacterial reductase enzyme deazaflavin-dependent Nitroreductase (Ddn) and reduced the form of cofactor F420. Pretomanid has demonstrated high anti-TB activity compared to other anti-TB drugs, with a minimum inhibitory concentration (MIC) ranging from 0.06 to 1 mcg/ml [19][20]. Through its inhibition of bacterial cell wall mycolic acid biosynthesis, Pretomanid has an aerobic bactericidal effect [21]. This enables the treatment of active tuberculosis infection by killing *Mycobacterium tuberculosis* bacteria that are actively reproducing. The molecular mechanism of a fore mentioned bactericidal effects is currently poorly understood, but it may involve effects on various genes that affect the cell wall, such as the *fas1* and *fas2* operons and the *efpA* and *iniBAC* operons. Theoperational genes are one or more set of potential targets. The above target relations' clinical effects are currently unknown [22].

Uses

To treat lung tuberculosis (TB) that is extensively drug resistant (XDR) or which cannot be tolerated or do not respond to treatment for multidrug-resistant (MDR)-TB, Pretomanid is used in a combination regimen with Bedaquiline and linezolid. Pretomanid stops tuberculosis from growing in the body [25].

Side effects

Difficult respiration problems with nerves, numbness, burning, or prickly feeling in arms, hands, legs, or feet swelling a face, lips, tongue, or throat. tremors, weakness, problems with balance, altered vision, shortness of breath, cough with mucus or blood, chest pain that gets worse when you breathe or cough, and nerve problems [23][24].

MOXIFLOXACIN

Mechanism of action

Moxifloxacin is an antibiotic that kills bacteria. By restricting DNA gyrase (topoisomerase II) and topoisomerase IV, essential bacterial catalysts involved in the replication, interpretation, fixation, and recombination of





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deoxyribonucleic acid, it impairs bacterial strength [26]. The Moxifloxacin binds the DNA gyrase and Topoisomerase very tightly. However, it restricts DNA gyrase in particular in gram-negative bacteria and *Streptococcus pneumoniae* and it inhibits ligase activity which cause cleavage of the DNA and damages DNA stands which results in incapable to repair the DNA stands thereafter inhibits DNA replication and causes cell death. Antibacterial fluoroquinolone Similar to other quinolones, moxifloxacin prevents bacterial cell DNA and RNA synthesis and inhibits DNA gyrase. Moxifloxacin has broad antimicrobial activity and is bactericidal. It differs slightly from earlier veterinary fluoroquinolones in terms of its chemical structure (eight methoxy substitutions). Compared to the veterinary fluoroquinolones (enrofloxacin, orbifloxacin, and marbofloxacin), this newer generation of drugs, like moxifloxacin, is more effective against gram-positive bacteria and anaerobes [27]. Pradofloxacin is a medication for animals that has been approved and has a similar spectrum. In some cases, pradofloxacin may be used in place of moxifloxacin in animals [28]. The development of a regimen that includes several bactericidal agents that the infecting organism is susceptible to is essential for the successful treatment of MDR-TB [29]. The lack of agents that are not only highly bactericidal but also nontoxic makes it difficult to achieve this goal. This is especially true given the extended duration of MDR treatment up to 24 months where toxicity can make it difficult for some patients to complete it. Treatment response can be slow due to the lower bactericidal activity and higher toxicity of many second-line agents like Linezolid, Prothionamide, and Cycloserine. This also explains why prolonged treatment is required. Patients who stop a portion of their treatment regimen due to exhaustion or toxicity run the risk of developing additional resistance [30]. There is a risk that patients will fall into a vicious cycle of failing regimens and increasing resistance, eventually leading to complete resistance, if the treatment they receive is not optimal. A lot of this issue is exacerbated by the shortfall of compelling medication vulnerability testing in some high-trouble nations, and that implies that managing a routine uncontrolled by powerlessness testing risks further opposition enhancement with diminishing choices for treatment [32]. The below given fig. 5 gives information about moxifloxacin mechanism of action.

Uses

A wide range of bacterial infections can be treated with moxifloxacin. Quinolone antibiotics are a class of drugs. These shows action by inhibiting the growth of bacteria. This antibiotic only treats infections caused by bacteria [31][32].

Side effects

Nausea, vomiting, dizziness, headache, weakness, or difficulty in falling sleep unusual bleeding and bruising, symptoms of a new infection such as a fever and sore throat that lasts for longer period, problems with the kidneys such as a change in the amount of urine, and problems with the liver such as nausea and vomiting that won't stop, unusual tiredness, stomach/abdominal pain, yellowing of the eyes and skin, and dark urine [33].

The Summary of newer anti-TB drugs

Bedaquiline, Pretomanid, Linezolid, and Moxifloxacin (BPALM) is a treatment for tuberculosis (TB) that has proven to be safer, more effective, and more rapid than previous treatments. The drugs in the BPALM regimen treat TB in various ways:

- i) Pretomanid: It eradicates TB-causing bacteria that are both dormant and actively reproducing [29].
- ii) Bedaquiline: Targets an enzyme's c-ring and s-subunit, which prevent ATP synthesis and disrupt the network of amino acid interactions.[31].
- iii) Linezolid: Inhibit MAO-A, which in turn may raise serotonin levels.
- iv) Moxifloxacin: An antibiotic that eliminates infection-causing bacteria. When it comes to treating patients with MDR or DR-TB, the BPALM regimen has demonstrated promising results in clinical trials [32]. If a patient exhibits a delayed treatment response within the first eight weeks, the regimen can be extended [33]. The below table 3 describe about the drugs and dose of BPALM regimen. These doses are not suitable for the children who are lesser than 14 years because it causes many major complication such as mutations, gene replication and there are no proper clinical studies conducted on Pretomanid so that there was another 9 months course duration for children that is oral regimen consists of Bedaquiline (which is used for 6 months), in combination with





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levofloxacin or moxifloxacin, ethionamide, ethambutol, isoniazid (high dose) and also pyrazinamide and clofazimine[34][35]. Table 4 gives information about drug structures, their mechanism and also side effects.

Advantages of using BPaLM regimen

A combination of drugs like moxifloxacin, linezolid, Bedaquiline, and Pretomanid are used because they:

- i) TB treatment time can be cut down with combination therapy.
- ii) The likelihood of the disease recurrence can be reduced with combination therapy.
- iii) Drug resistance can be slowed down with combination therapy.
- iv) Combination regimens have demonstrated greater bactericidal activity than first-line regimens in animal models [35].

Disadvantages of BPaLM regimen

- i) Bedaquiline, Pretomanid, and Linezolid (BPaL) as a combination drug therapy for tuberculosis (TB) may have drawbacks, including: Negative effects on Peripheral neuropathy, optic neuritis, myelosuppression, hepatotoxicity, and pancreatitis.
- ii) Linezolid causes toxicity when taken in large quantities, linezolid can cause optic neuropathy, peripheral neuropathy, and bone marrow toxicity.
- iii) Bedaquiline causes prolongation of QT wave- QT prolongation brought on by Bedaquiline may alter cardiac rhythm.
- iv) Pretomanid causes musculoskeletal pain, headaches, nausea, acne, and vomiting, Pretomanid can harm the liver, eyes, and reproductive system [34][35].

Rationale behind BPaLM regiment

- i) A robust and multi-pronged attack on *Mycobacterium tuberculosis* was provided by these drugs, which were chosen because they target various critical bacterial functions like energy production, protein synthesis, cell wall synthesis, and DNA replication. The chances of the bacteria surviving and developing resistance are significantly reduced by employing this multi-target strategy.
- ii) MDR and XDR TB, which are resistant to standard first-line treatments, have all been shown to be effective with each of these medications. Particularly Bedaquiline and Pretomanid have become crucial in combating these resistant strains of tuberculosis.
- iii) Drug-resistant forms of traditional TB treatment frequently necessitate lengthy treatment regimens, lasting anywhere from 18 to 24 months. Patient adherence and outcomes are enhanced by the BPaLM regimen's shorter treatment duration of typically 6 months.
- iv) When choosing these drugs, safety and tolerability are also taken into consideration. Patients infected with strains that are resistant to isoniazid and rifampicin known as multidrug-resistant (MDR) TB are practically incurable by standard first-line treatment. While some medications, such as Linezolid may carry risks of toxicity (such as bone marrow suppression or neuropathy) MDR-TB patients are virtually incurable. MDR-TB strains that are resistant to fluoroquinolones and second-line injectable drugs are referred to as extensively drug-resistant (XDR) TB and there were approximately 4,50,000 new cases and 1,70,000 members deaths in 2012[36].

CONCLUSION

The BPaLM regimen consisting of Bedaquiline, Pretomanid, Linezolid, Moxifloxacin represents a significant breakthrough in the treatment of multi drug resistant tuberculosis. The BPaLM regimen is a crucial addition to the global fight against MDR-TB with its novel mechanism of action it reduces treatment duration (6months). This combination of drugs improves its efficacy and also stops the chance of reoccurrence. Normally to treat TB it used to take 18 months treatment by using nearly more than 14000 pills overall by using some of the first line and second line drugs but after this BPaLM regimen it can treat within 6months by using less than 750 pills. Over all this treatment helps the patient to a certain extent and provides a greater relief from treatment of Tuberculosis. As the global health





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community continues to work towards ending the TB epidemic, the BPaLM regimen will undoubtedly play a vital role in achieving this goal.

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Table 1: Classification of anti-tubercular drugs based on minimum inhibitory concentration

ANTI TUBERCULAR DRUGS	
FIRST LINE DRUGS	SECOND LINE DRUGS
ISONIAZID(H) RIFAMPICIN(R) PYRAZINAMIDE(Z) ETHAMBUTOL(E) STREPTOMYCIN(S)	*AMINOGLYCOSIDES Kanamycin Amikacin *MACROLIDES Azithromycin Clarithromycin *FLUORO QUINOLONES Levofloxacin Moxifloxacin *PARA AMINO SALICYLIC ACID *BEDAQUILINE *CYCLOSERINE *ETHIONAMIDE *CAPEROMYCIN *THIACETAMIDE

Table 2: Classification of anti-tubercular drugs based on efficacy

Group A	<ul style="list-style-type: none"> • Levofloxacin (LFX) or Moxifloxacin (MFX) • Bedaquiline (BDQ) • Linezolid (LZD)
Group B	<ul style="list-style-type: none"> • Clofazamine (CFZ) • Cycloserine (CS) or Terizidone (TRD)
Group C	<ul style="list-style-type: none"> • Ethambutol (E) • Delamanid (DLM) • Pyrazinamide (Z) • Imipenem-Cilastatin (IPM-CIN) or Meropenem (MPM)





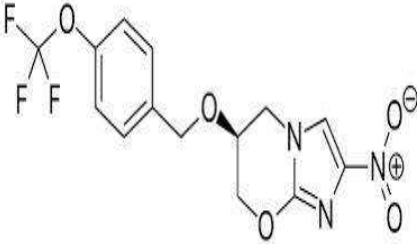
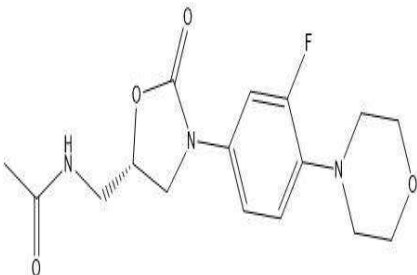
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	<ul style="list-style-type: none"> • Amikacin (Am) or Streptomycin (S) • Ethionamide (ETO) or Prothionamide (PTO) • Para amino salicylic acid (PAS)
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Table 3: BPaLM regimen

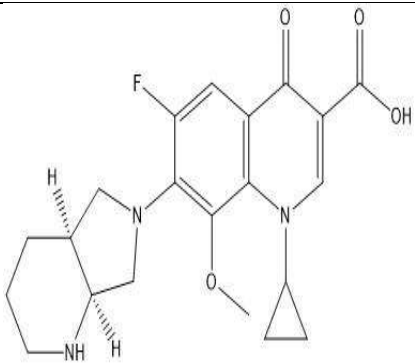
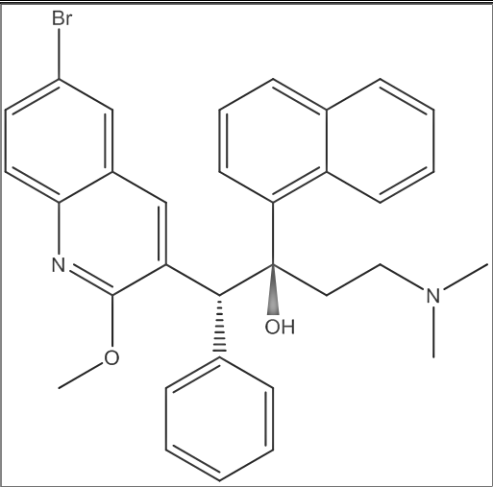
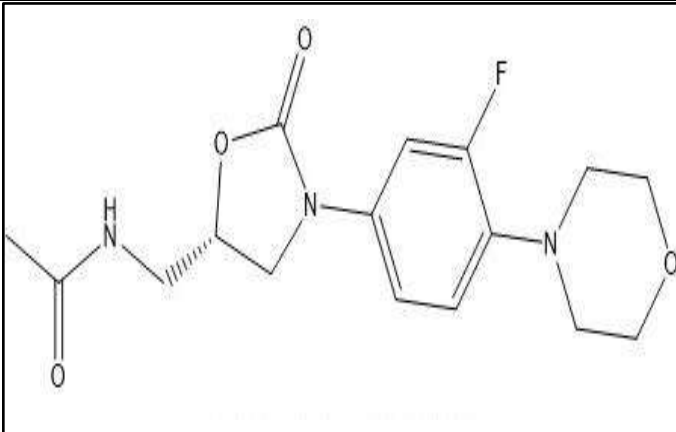
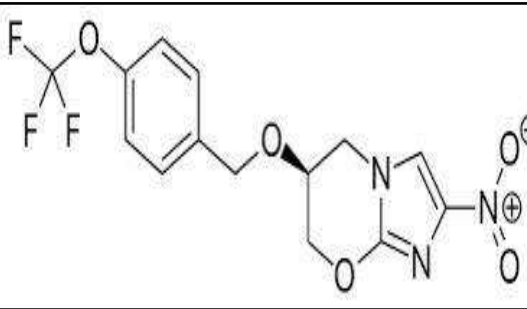
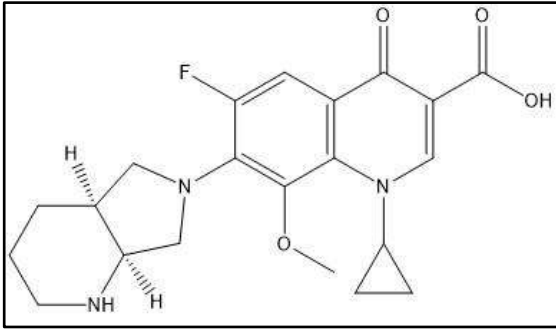
DRUG	DOSE
1)Bedaquiline (100 mg tablet)	400 mg once daily for 2 weeks, then 200 mg 3 times per week afterwards OR 200 mg daily for 8 weeks, then 100 mg daily
2)Pretomanid (200 mg tablet)	200 mg once daily
3)Linezolid (600 mg tablet)	600 mg once daily
4)Moxifloxacin (400 mg tablet)	400 mg once daily

Table 4: BPaLM drugs mechanism and side effects

Name	Structure	MOA	Side Effects
Bedaquiline (B)		It inhibits ATP synthase enzyme, that interrupts energy production and causes cell death	Joint pains, headaches, chest pain, chest pain, liver dysfunction, coughing up blood.
Pretomanid (Pa)		It disrupts mycobacterial cell wall synthesis and generates nitrogen species and leads to bacterial death	Numbness, burning, or prickly feeling in arms, hands, legs, or feet, tremors, weakness, altered vision, shortness of breath
Linezolid (L)		It inhibits bacterial protein synthesis by binding to 50S ribosomal subunits	Decreased platelets, white blood cell counts, headache, haemoglobin levels, diarrhoea, elevated pancreatic and liver functions



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Moxifloxacin (M)		It inhibits Topoisomerase ii & Topoisomerase iv enzymes which are essential for DNA replication	Nausea, vomiting, dizziness, headache, weakness, difficulty in falling sleep unusual bleeding and bruising, yellowing of the eyes and skin, and dark urine.
		<p>Fig.1: Bedaquiline CLogP: 7.2505 Mol.Wt.: 555.504 g/mol Chemical Formula: C₃₂H₃₁BrN₂O₂</p> <p>Fig.2: Linezolid CLogP: 0.168099 Mol. Wt: 337.346 g/mol Chemical Formula: C₁₆H₂₀FN₃O₄</p>	
		<p>Fig.3: Pretomanid CLogP: 2.7921 Mol.Wt.: 359258 g/mol Chemical formula: C₁₄H₁₂F₃N₃O₅</p> <p>Fig.4: Moxifloxacin CLogP: -0.0823941 Mol. Wt.: 401.431g/mol Chemical formula: C₂₁H₂₄FN₃O₄</p>	





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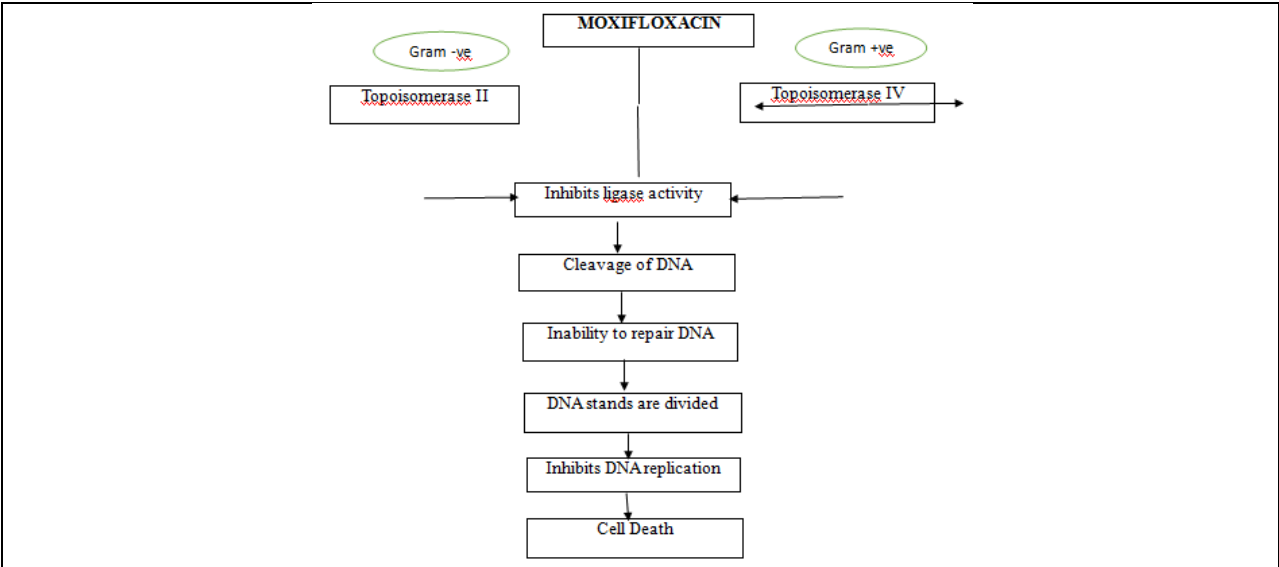


Fig 5: Moxifloxacin mechanism of action





Innovative Approaches to Kidney Disease Detection via Automated Urinalysis

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ABSTRACT

The early and accurate diagnosis of kidney diseases is crucial for effective treatment and improved patient outcomes. Automated analysis of urine samples has emerged as a reliable, cost-effective, and non-invasive diagnostic approach. This study explores the integration of advanced technologies, including image processing, machine learning, and biochemical assays, to enhance the precision and efficiency of kidney disease diagnosis. By analyzing key parameters such as protein levels, glucose, pH, specific gravity, and microscopic elements like red blood cells, white blood cells, and casts, the system provides comprehensive insights into renal health. The proposed automated system minimizes human error, reduces processing time, and enables real-time monitoring, making it a valuable tool for clinical laboratories. Results demonstrate a significant correlation between automated findings and clinical outcomes, supporting the system's potential for widespread adoption in early kidney disease detection and management.

Keywords: Automated Urine Analysis, Kidney Disease Diagnosis, Non-Invasive Diagnostics, Urinalysis Automation, Renal Health Monitoring



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INTRODUCTION

Early medical diagnoses were grounded in what ancient physicians could observe visually and aurally, often incorporating the examination of human specimens. The ancient Greek medical tradition linked all diseases to imbalances in bodily fluids known as humors. By the late medieval era, uroscopy had become a common practice among physicians for diagnostic purposes[1,2]. Acute kidney injury (AKI) is a common condition observed in hospitalized and critically ill patients, characterized by a sudden decline in renal excretory function, often associated with other underlying illnesses[3]. The causes of AKI are typically categorized as prerenal, intrinsic renal, or postrenal. The microscopic examination of urine in AKI reveals a range of findings depending on the underlying etiology. Prerenal AKI often presents with a bland urinary sediment containing minimal hyaline casts, while intrinsic renal AKI may show muddy brown casts, coarse granular casts, epithelial cell casts, and renal tubular epithelial cells (RTEC). Additionally, findings such as hematuria, red cell fragments, red cell casts, and white cell casts can indicate glomerular involvement[4-5]. Chronic kidney disease (CKD) affects approximately 8% to 16% of the global population and often goes unrecognized by both patients and healthcare providers[6-9]. It is defined by a glomerular filtration rate (GFR) below 60 mL/min/1.73 m², albuminuria of 30 mg or more per 24 hours, or persistent markers of kidney damage—such as hematuria or structural abnormalities like polycystic or dysplastic kidneys—for a duration exceeding three months[10]. CKD is notably more prevalent in low- and middle-income countries compared to high-income nations [11].

MATERIAL AND METHODS

The study was conducted using a total of 98 urine samples collected from individuals meeting the inclusion criteria. The samples were sourced from JITM Skills Private Limited, Pathology laboratory, Noida. Ensuring a representative mix of patients with and without kidney disease.

Sample Collection and Preparation

Urine samples were collected in sterile containers following standard protocols to minimize contamination. Each sample was labeled with a unique identity and stored at 4°C, until analysis. Prior to processing, the samples were brought to room temperature and gently mixed.

RESULT

The automated analysis of urine samples for kidney disease diagnosis involved the measurement and evaluation of several key parameters. These included ketones, bilirubin, glucose, pH, protein, and blood, with the results providing valuable insights into the diagnostic process.

Glucose

Urinary glucose levels are commonly used to assess conditions such as diabetes mellitus or impaired glucose tolerance. Automated analysis of glucose concentrations in the 98 urine samples revealed the following distribution of results:

- **Normal (Negative):** 89 samples
- **Trace:** 6 samples
- **Positive:** 3 samples

The majority of the samples (89 out of 98) exhibited normal (negative) glucose levels, indicating no significant abnormality related to glucose excretion. A smaller proportion showed trace (6 samples) or positive (3 samples) glucose levels, which could suggest potential issues such as diabetes-related kidney complications in the affected individuals.



**Vishant Pal et al.,****Trace Glucose Levels (6 samples)**

Six samples exhibited trace amounts of glucose, suggesting a mild elevation in glucose excretion. This could indicate early signs of metabolic disturbances, warranting further monitoring or clinical investigation.

Positive Glucose Levels (3 samples)

Three samples displayed elevated glucose levels, indicative of potential diabetes-related kidney complications. These findings emphasize the need for further assessment of renal function and possible intervention in individuals with underlying metabolic disorders. The majority of urine samples (89 out of 98) displayed glucose levels within the normal range, suggesting no significant abnormalities related to diabetes mellitus or impaired glucose tolerance. However, a smaller subset of samples demonstrated trace and positive glucose levels, which may indicate potential underlying health concerns.

Ketones

Ketones are metabolic byproducts that can serve as indicators of conditions such as diabetic ketoacidosis or starvation. Automated analysis of urine samples revealed the following distribution of ketone levels:

- **Normal (Negative):** 97 samples
- **Elevated:** 1 sample

The majority of the samples (97 out of 98) showed normal (negative) ketone levels, suggesting no significant metabolic disturbances. However, one sample exhibited elevated ketone levels, which may point to a potential metabolic abnormality requiring further investigation. This finding emphasizes the importance of monitoring ketone levels as part of a comprehensive approach to diagnosing kidney-related metabolic conditions.

Bilirubin

Bilirubin in urine may indicate liver disease or hemolytic disorders. Automated analysis of 98 urine samples for kidney disease diagnosis revealed the following distribution of bilirubin levels:

- **Normal (Negative):** 96 samples
- **Positive Bilirubin:** 2 samples

The majority of the samples (96 out of 98) did not show detectable bilirubin, suggesting no significant bilirubinuria. However, two samples tested positive for bilirubin, which could be indicative of underlying liver-related abnormalities or hemolysis affecting the urinary system. These findings highlight the importance of bilirubin monitoring in the context of kidney disease diagnosis, particularly for detecting potential hepatic or hematological issues. The automated analysis effectively identified bilirubin levels, aiding in the differential diagnosis of kidney diseases linked to systemic abnormalities. These findings underscore the capability of automated urine analysis in detecting and quantifying critical biomarkers associated with kidney disease. By integrating advanced technologies such as biochemical assays and image processing algorithms, the system enabled a rapid, objective assessment, ultimately improving diagnostic accuracy and efficiency in clinical settings.

pH

Urine pH is a critical parameter for assessing acid-base balance and renal function. Automated analysis of pH values in the 98 urine samples revealed the following results:

- **pH 5.5:** 2 samples
- **pH 6.0:** 13 samples
- **pH 7.0:** 1 sample
- **pH 7.5:** 1 sample
- **Normal pH (within range):** 81 samples

The majority of the samples (81 out of 98) exhibited normal pH levels, typically ranging from 5.0 to 7.5, indicating a balanced acidity/alkalinity in the urine. A small number of samples exhibited pH values outside this range, suggesting potential deviations in renal function:



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- Two samples with a pH of 5.5 indicated increased acidity, which could suggest renal tubular dysfunction or other metabolic disturbances.
- Thirteen samples with a pH of 6.0 were slightly below the normal range, potentially reflecting early signs of renal imbalance or dietary influences.
- One sample with a pH of 7.0 was within the upper limit of the normal range, while another sample with a pH of 7.5 was at the upper end, indicating mild alkalinity. The analysis of urine pH levels revealed variability, with a small subset of samples displaying abnormal acidity or alkalinity. This highlights the significance of comprehensive urine analysis in evaluating renal function and maintaining acid-base balance. Further investigation of cases with abnormal pH, in conjunction with other clinical parameters, may offer valuable insights into underlying metabolic disorders or renal dysfunction. Automated urine analysis proves to be an effective screening tool for identifying subtle imbalances in the urinary tract, supporting early detection and timely management of kidney-related conditions.

Protein

Proteinuria, defined as the presence of excess protein in the urine, is a key indicator of kidney disease. Automated analysis of protein levels in the 98 urine samples yielded the following results:

- **Normal (Negative):** 92 samples
- **Trace Proteinuria:** 3 samples
- **Positive Proteinuria:** 3 samples

The majority of the samples (92 out of 98) exhibited normal protein levels, indicating no significant proteinuria and suggesting intact glomerular filtration in these cases. These findings underscore the importance of protein quantification in diagnosing renal abnormalities, as deviations from normal levels may indicate underlying glomerular damage or other renal dysfunctions.

Protein levels in the urine were within the normal range in the majority of samples, indicating an absence of significant proteinuria or renal dysfunction.

- **Trace Proteinuria (3 samples):** Trace amounts of protein were detected in three samples, indicating a mild elevation that may require further evaluation or ongoing monitoring.
- **Positive Proteinuria (3 samples):** Elevated protein levels were identified in three samples, consistent with proteinuria, a hallmark of kidney disease. These findings suggest the presence of underlying renal pathology in these individuals.

Blood

The presence of blood in urine (hematuria) is a significant finding that can indicate various conditions, including urinary tract infections or kidney stones. Automated analysis of urine samples detected blood cells in the sediment, contributing to the identification of underlying kidney pathologies.

The analysis of 98 urine samples for kidney disease diagnosis revealed the following distribution:

- **Normal (Negative):** 90 samples
- **Trace Hematuria:** 2 samples
- **Positive Hematuria:** 6 samples

The majority of samples (90 out of 98) demonstrated no detectable blood, indicating the absence of hematuria in these cases. However, two samples showed trace amounts of blood, suggesting mild hematuria that may warrant further investigation. Six samples exhibited positive hematuria, pointing to potential underlying renal or urinary tract abnormalities.

These findings emphasize the role of automated urine analysis in detecting hematuria and its significance in diagnosing kidney-related conditions.

Blood was absent in the majority of urine samples, indicating no significant hematuria or evidence of renal bleeding.

- **Trace Hematuria (2 samples):** Trace amounts of blood were detected in two samples, indicating a minor presence that may require additional evaluation.



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- **Positive Hematuria (6 samples):** Six samples showed elevated levels of blood in the urine, consistent with hematuria. This finding suggests the possibility of underlying kidney pathology or other conditions impacting the urinary tract.

DISCUSSION

Automated urine analysis proves to be an efficient and reliable method for evaluating biomarkers related to kidney disease and systemic conditions.

Glucose

Most samples (89/98) were normal, with trace (6) and positive (3) levels indicating potential diabetes or metabolic disorders. Early detection of glycosuria can aid in identifying diabetic complications.

Ketones

Only one sample showed elevated ketones, highlighting a low prevalence of metabolic disturbances such as ketoacidosis or starvation.

Bilirubin

Positive bilirubin in 2 samples suggests potential liver or hemolytic abnormalities, reinforcing its importance in systemic evaluations.

pH

While 81 samples showed normal pH, deviations (e.g., acidic or alkaline values) in a few cases suggest possible renal tubular dysfunction or metabolic imbalances.

Protein

Proteinuria was absent in 92 samples, with trace (3) and positive (3) levels indicating potential glomerular damage or early renal pathology.

Blood

Hematuria was detected in 8 samples (2 trace, 6 positive), pointing to possible infections, stones, or glomerulonephritis. These findings demonstrate the utility of automated urine analysis in early disease detection and monitoring. By enabling rapid, objective assessments, it supports timely interventions and improves diagnostic accuracy in clinical practice. Future studies should validate these findings over larger populations and integrate additional biomarkers for enhanced diagnostic capabilities.

Conflict of Interest

The authors declare no conflict of interest. The study was conducted independently, without any financial or commercial influence that could affect the research outcomes. All data analysis, interpretation, and reporting were carried out with the sole objective of advancing scientific knowledge and improving clinical diagnostics.

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Table 1:-Analysis of 98 urine samples for kidney disease diagnosis, glucose levels

S.NO	Total patient	Negative Patient	Positive Patient	Trace
1	98	89	3	6

Table 2:-Analysis of 98 urine samples for kidney disease diagnosis, Ketonebodies

S.NO	Total patient	Negative Patient	Positive Patient
1	98	97	1

Table 3:-Analysis of 98 urine samples for kidney disease diagnosis, Bilirubin

S.NO	Total patient	Negative Patient	Positive Patient
1	98	96	2

Table 4:-Analysis of 98 urine samples for kidney disease diagnosis, pH

S.NO	Total patient	Negative Patient	5.5	6.0	7.0	7.5
1	98	80	2	13	1	1

Table 5:-Analysis of 98 urine samples for kidney disease diagnosis, Protein

S.NO	Total patient	Negative patient	Positive Patient	Trace
1	98	92	3	3

Table 6:-Analysis of 98 urine samples for kidney disease diagnosis, Blood

S.NO	Total patient	Negative Patient	Positive Patient	Trace
1	98	90	6	2





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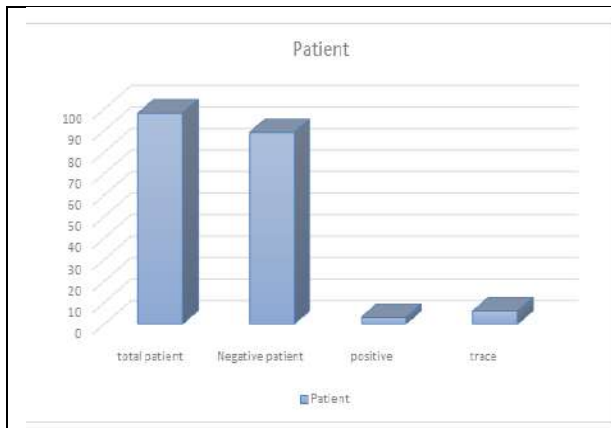


Fig 1-Analysis of 98 urine samples for kidney disease diagnosis, glucose levels

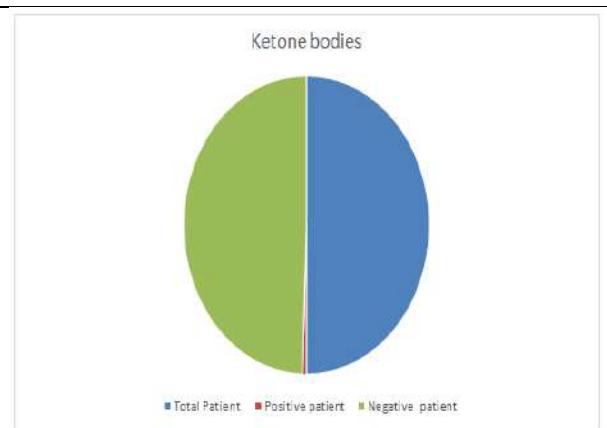


Fig 2-Analysis of 98 urine samples for kidney disease diagnosis, Ketone bodies

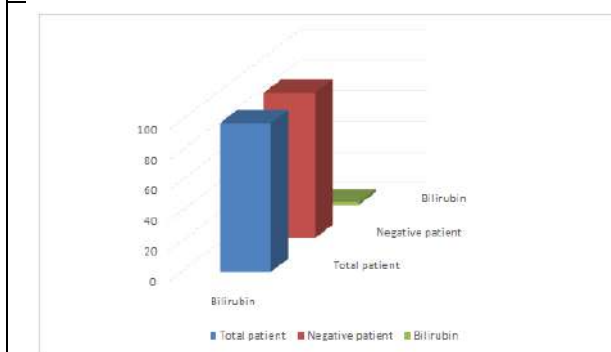


Fig 3-Analysis of 98 urine samples for kidney disease diagnosis, Bilirubin

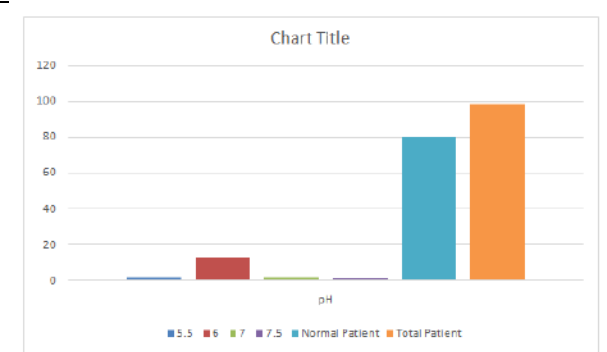


Fig 4-Analysis of 98 urine samples for kidney disease diagnosis, pH

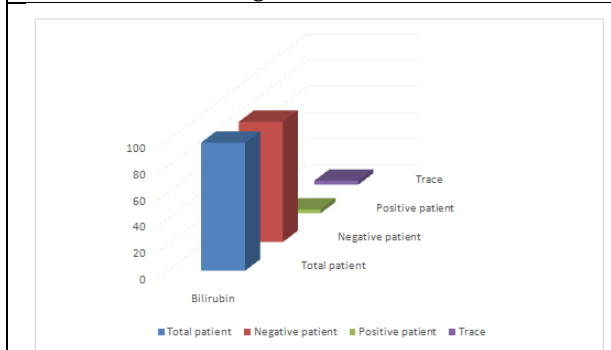


Fig 5-Analysis of 98 urine samples for kidney disease diagnosis, protein

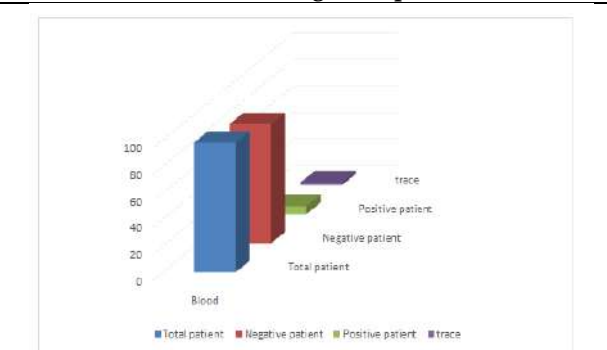


Fig 6-Analysis of 98 urine samples for kidney disease diagnosis, Blood





Some New Types of Nano Closed sets in Nano Topological Spaces

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ABSTRACT

In this paper, I present new type of N-cld sets within NI-cld, NI-open sets, along with various properties associated with them.

Keywords: NI-cld, NI-open, $N\hat{g}$ -cld, NI-int, NI-cl.

INTRODUCTION

Topology is a division of Mathematics, primarily aimed at clarifying and exploring the notions of continuity within the Mathematics. Introduced [5] the weakly open sets, which they defined via approximations and boundary regions of a subset from a universe U utilizing an equivalence relation, alongside definitions for nano closed sets, nano interior, and nano closure. Similarly, S. Jafari and T. Noiri [4], introduced the another generalization of closed sets. Furthermore, introduced [3] on nano semi-generalized closed sets.

PRELIMINARIES

Throughout this paper U constitute nano topological spaces (NTPS) on which no separation axioms are assumed except in any other case mentioned.

Definition 2.1.[5]

Let U be a non-empty finite set of objects called the universe and R be an equivalence relation on U . The pair (U, R) is said to be the approximation space. Let $X \subseteq U$.





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1. The lower approximation of X w.r.t R , $L_R(X) = \cup\{R(X): R(X) \subseteq X, x \in U\}$ where $R(X)$ denotes the equivalence class determined by $x \in U$.
2. The upper approximation of X w.r.t R , $U_R(X) = \cup\{R(X): R(X) \cap X \neq \Phi, x \in U\}$.
3. The boundary region of X w.r.t R , $Br(X) = U_R(X) - L_R(X)$.

Definition 2.2. [5]

Let U be the universe, R be an equivalence relation on U and $\tau_R(X) = \{\Phi, L_R(X), U_R(X), Br(X), U\}$ where $X \subseteq U$. Then $U_R(X)$ satisfies the following axioms:

1. Φ and $U \in \tau_R(X)$.
2. The union of the elements of any sub-collection of $\tau_R(X)$ is in $\tau_R(X)$.
3. The intersection of the elements of any finite subcollection of $\tau_R(X)$ is in $\tau_R(X)$.

Then $(U, \tau_R(X))$ is called the nano topological space (NTPS).

Definition 2.3

Let $K \subseteq U$. Then K is called

- (i) NSO [3] if $K \subseteq Ncl(Nint(K))$.
- (ii) NPO [2] if $K \subseteq Nint(Ncl(K))$.
- (iii) NRO [6] if $K = Nint(Ncl(K))$.
- (iv) NSPO [3] if $K \subseteq Ncl(Nint(Ncl(K)))$.
- (v) $N\alpha O$ [1] if $K \subseteq Nint(Ncl(Nint(K)))$.

Definition 2.4

Let $K \subseteq U$. Then K is called

1. Ng-cld [7] if $Ncl(K) \subseteq M$ where $K \subseteq M$ and M is NO.
2. Ngp-cld [6] if $Npcl(K) \subseteq M$ where $K \subseteq M$ and M is NO.
3. Ngsp-cld [3] if $Nspcl(K) \subseteq M$ where $K \subseteq M$ and M is NO.
4. $Ng\alpha$ -cld [5] if $N\alpha cl(K) \subseteq M$ where $K \subseteq M$ and M is NO.
5. $N\hat{g}$ -cld [6] if $Ncl(K) \subseteq M$ where $K \subseteq M$ and M is NSO.
6. N^*g -cld [7] if $Ncl(K) \subseteq M$ where $K \subseteq M$ and M is $N\omega O$.
7. Nsg-cld [4] if $Nscl(K) \subseteq M$ where $K \subseteq M$ and M is NSO.
8. Ngs-cld [7] if $Nscl(K) \subseteq M$ where $K \subseteq M$ and M is NO.
9. $N\alpha g$ -cld [4] if $N\alpha cl(K) \subseteq M$ where $K \subseteq M$ and M is $N\alpha O$.

NEW TYPE OF NI-cld sets

Definition 3.1

Let K be NI-closed (NI-cld) if $Nsgcl(K) \subseteq M$ where $K \subseteq M$ and M is $N\hat{g}O$.

Proposition 3.2

Each N-cld \Rightarrow NI-cld.

Proof

Let K be a N-cld and $K \subseteq U$. Let $K \subseteq M$ and M is every $N\hat{g}O$. Then K is N-cld, $Ncl(K) = K$. Since each N-cld is NS-cld, $Nsgcl(K) \subseteq Ncl(K) = K \subseteq M$. Therefore $Nsgcl(K) \subseteq V$ and K is NI-cld.

Remark 3.3

The reverse of the above proposition doesn't necessarily hold.





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Example 3.4

Consider $\mathbb{U} = \{n_1, n_2, n_3, n_4\}$; $\mathbb{U}/R = \{\{n_1\}, \{n_3\}, \{n_2, n_4\}\}$ and $X = \{n_1, n_2\}$. We have $\tau_R(X) = \{\Phi, \{n_1\}, \{n_2, n_4\}, \{n_1, n_2, n_4\}, \mathbb{U}\}$. Here $\{n_1\}$ is NI-cld, $\{n_1\}$ isn't N-cld.

Proposition 3.5

Each NR-cld \Rightarrow NI-cld.

Proof

Let K be a NR-cld and $K \subseteq \mathbb{U}$. Let $K \subseteq M$ and M is $N\hat{g}O$. Then K is NR-cld, we have $Nrcl(K) = K$. Since each NR-cld is N-cld, $Ncl(K) \subseteq Nrcl(K)$. Since each N-cld is NS-cld, $Nsgcl(K) \subseteq Ncl(K)$. We have $Nsgcl(K) \subseteq Nrcl(K) = K \subseteq M$. Therefore $Nsgcl(K) \subseteq M$ and K is NI-cld.

Remark 3.6

The reverse of the above proposition doesn't necessarily hold.

Example 3.7

Consider $\mathbb{U} = \{n_1, n_2, n_3, n_4\}$; $\mathbb{U}/R = \{\{n_1\}, \{n_3\}, \{n_2, n_4\}\}$ and $X = \{n_1, n_2\}$. We have $\tau_R(X) = \{\Phi, \{n_1\}, \{n_2, n_4\}, \{n_1, n_2, n_4\}, \mathbb{U}\}$. Here $\{n_2, n_4\}$ is NI-cld, $\{n_2, n_4\}$ isn't NR-cld.

Proposition 3.8

Each N^*g -cld \Rightarrow NI-cld.

Proof

Let K be a N^*g -cld and $K \subseteq \mathbb{U}$. Let $K \subseteq M$ and M is $N\hat{g}O$. Since K is N^*g -cld, $Ncl(K) \subseteq M$. Also since each N-cld is NS-cld, $Nsgcl(K) \subseteq Ncl(K) \subseteq M$. Therefore $Nsgcl(K) \subseteq M$ and K is NI-cld.

Remark 3.9

The reverse of the above proposition doesn't necessarily hold.

Example 3.10

Consider $\mathbb{U} = \{n_1, n_2, n_3, n_4\}$; $\mathbb{U}/R = \{\{n_1\}, \{n_3\}, \{n_2, n_4\}\}$ and $X = \{n_1, n_2\}$. We have $\tau_R(X) = \{\Phi, \{n_1\}, \{n_2, n_4\}, \{n_1, n_2, n_4\}, \mathbb{U}\}$. Here $\{n_2, n_4\}$ is NI-cld, $\{n_2, n_4\}$ isn't N^*g -cld.

Proposition 3.11

Each NI-cld \Rightarrow Ngsp-cld.

Proof

Let K be a NI-cld and $K \subseteq \mathbb{U}$. Let $K \subseteq M$ and M is N-open. Since each NS-cld is NSP-cld and K is NI-cld. Therefore $Nspcl(K) \subseteq Nsgcl(K) \subseteq M$. Therefore $Nspcl(K) \subseteq M$ and K is Ngsp-cld.

Remark 3.12

The reverse of the above proposition doesn't necessarily hold.

Example 3.13

Consider $\mathbb{U} = \{n_1, n_2, n_3, n_4\}$; $\mathbb{U}/R = \{\{n_2\}, \{n_3\}, \{n_1, n_4\}\}$ and $X = \{n_1, n_2\}$. We have $\tau_R(X) = \{\Phi, \{n_2\}, \{n_1, n_4\}, \{n_1, n_2, n_4\}, \mathbb{U}\}$. Here $\{n_1, n_2\}$ is Ngsp-cld $\{n_1, n_2\}$ isn't NI-cld.

Proposition 3.14

Each NI-cld \Rightarrow Nsg-cld.





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Proof

Let K be a NI-cld and $K \subseteq U$. Let $K \subseteq M$ and M is N-open. Since each Nano open is $N\hat{g}O$ and K is NI-cld, $Nsgcl(K) \subseteq M$. Therefore K is Nsg-cld.

Remark 3.15

The reverse of the above proposition doesn't necessarily hold.

Example 3.16

Consider $U = \{a_1, b_1, c_1, d_1\}$; $U/R = \{\{b_1\}, \{c_1\}, \{a_1, d_1\}\}$ and $X = \{a_1, b_1\}$. We have $\tau_R(X) = \{\Phi, \{b_1\}, \{a_1, d_1\}, \{a_1, b_1, d_1\}, U\}$. Here $\{d_1\}$ is Nsg-cld, $\{d_1\}$ isn't NI-cld.

Remark 3.17

The reverse of the above proposition doesn't necessarily hold.

Example 3.18

Consider $U = \{n_1, n_2, n_3, n_4\}$; $U/R = \{\{n_1\}, \{n_3\}, \{n_2, n_4\}\}$ and $X = \{n_1, n_2\}$. We have $\tau_R(X) = \{\Phi, \{n_1\}, \{n_2, n_4\}, \{n_1, n_2, n_4\}, U\}$. Here $\{n_2, n_3\}$ is Ng-cld, $\{n_2, n_3\}$ isn't NI-cld.

Example 3.19

Here the above Example 3.18, $\{n_2, n_4\}$ is NI-cld but not Ng-cld.

Remark 3.20

The reverse of the above proposition doesn't necessarily hold.

Example 3.21

Consider $U = \{a_1, b_1, c_1, d_1\}$; $U/R = \{\{a_1\}, \{b_1\}, \{c_1, d_1\}\}$ and $X = \{a_1, c_1\}$. We have $\tau_R(X) = \{\Phi, \{a_1\}, \{c_1, d_1\}, \{a_1, c_1, d_1\}, U\}$. Here $\{d_1\}$ is Ngp-cld, $\{d_1\}$ isn't NI-cld.

Example 3.22

In Example 3.21, Here $K = \{c_1, d_1\}$ is NI-cld, K isn't Ngp cld.

Remark 3.23

NI-cld and Nsg-cld are independent.

Example 3.24

Consider $U = \{a_1, b_1, c_1, d_1\}$; $U/R = \{\{a_1\}, \{d_1\}, \{b_1, c_1\}\}$. Let $X = \{a_1, c_1\}$. We have $\tau_R(X) = \{\Phi, \{a_1\}, \{b_1, c_1\}, \{a_1, b_1, c_1\}, U\}$. Here $\{a_1, b_1\}$ is Nsg-cld, $\{a_1, b_1\}$ isn't NI-cld and $\{b_1, c_1\}$ is NI-cld, $\{b_1, c_1\}$ is not Nsg-cld.

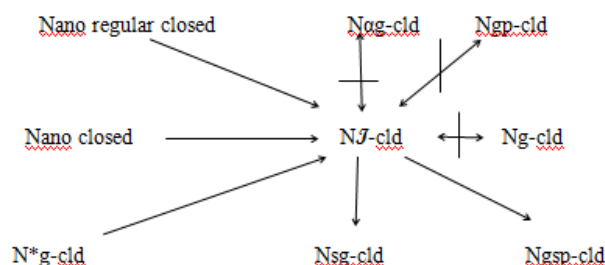
Remark 3.25

We obtain the following diagram





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SOME PROPERTIES OF NI-CLD SETS

Theorem 4.1

If $K \subseteq U$ is NI-cld such that $K \subseteq L \subseteq \text{Nscl}(K)$. Show that L is also NI-cld.

Proof

Let V be $\hat{N}\hat{g}O$ in U such that $L \subseteq M$. Then $K \subseteq M$. Since K is NI-cld, $\text{Nscl}(K) \subseteq M$. We have, $\text{Nscl}(L) \subseteq \text{Nscl}(\text{Nscl}(K)) = \text{Nscl}(K) \subseteq M$. Then $\text{Nscl}(L) \subseteq M$ and L is NI-cld.

Theorem 4.2

If K is $\hat{N}\hat{g}O$ and NI-cld, then K is NS-cld.

Proof

Let $K \subseteq K$ where K is $\hat{N}\hat{g}O$ and NI-cld. Then $\text{Nscl}(K) \subseteq K$ and $K \subseteq \text{Nscl}(K)$. Therefore $K = \text{Nscl}(K)$ and K is NS-cld.

Theorem 4.3

If K and L are NI-cld in U , prove that $K \cup L$ is NI-cld.

Proof

Consider K and L be each two NI-cld in U s.t $K \subseteq M$ and $L \subseteq M$ where M is $\hat{N}\hat{g}O$ in U . Therefore $K \cup L \subseteq M$. Then K and L are NI-cld, $\text{Nscl}(K) \subseteq M$ and $\text{Nscl}(L) \subseteq M$. We have $\text{Nscl}(K) \cup \text{Nscl}(L) \subseteq M$. Then $\text{Nscl}(K \cup L) \subseteq M$ and $K \cup L$ is NI-cld.

Theorem 4.4

If K and L are NI-cld in U , show that $K \cap L$ is NI-cld.

Proof

Consider K and L be each two NI-cld in U s.t $K \subseteq M$ and $L \subseteq M$ where M is $\hat{N}\hat{g}O$ in U . Therefore $K \cap L \subseteq M$. Then K and L are NI-cld, $\text{Nscl}(K) \subseteq M$ and $\text{Nscl}(L) \subseteq M$. Therefore $\text{Nscl}(K) \cap \text{Nscl}(L) \subseteq V$. Then $\text{Nscl}(K \cap L) \subseteq V$ and $K \cap L$ is NI-cld.

Theorem 4.5

For all $x \in U$, either $\{x\}$ is $\hat{N}\hat{g}$ -cld or $\{x\}^c$ is NI-cld.

Proof

If $\{x\}$ is not $\hat{N}\hat{g}$ -cld. Then $\{x\}^c$ isn't $\hat{N}\hat{g}O$. Then only $\hat{N}\hat{g}O$ containing $\{x\}^c$ is the space U itself. Then $\text{Nscl}(\{x\}^c) \subseteq U$ and so $\{x\}^c$ is NI-cld.





Amala Priya

Theorem 4.6

If a subset K of \mathbb{U} is NI-cld iff $\text{Nscl}(K) - K$ contains no non-empty $\text{N}\hat{g}$ -cld.

Proof

Let K be a NI-cld . Let F be a non-empty $\text{N}\hat{g}$ -cld subset of $\text{Nscl}(K) - K$. We have $F \subseteq \text{Nscl}(K) - K$. Then $F \subseteq \text{Nscl}(K) - (\mathbb{U} - F)$. Since $\mathbb{U} - F$ is $\text{N}\hat{g}\text{O}$ and K is NI-cld , $\text{Nscl}(K) \subseteq \mathbb{U} - F$. Then $\text{Nscl}(K) \subseteq F^c$ and $F \subseteq [\text{Nscl}(K)]^c$, $F \subseteq \text{Nscl}(K) \cap [\text{Nscl}(K)]^c = \Phi$. Which is a contradiction. Then $\text{Nscl}(K) - K$ does not contain any non-empty $\text{N}\hat{g}$ -cld.

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Effect of Structured Teaching Programme on Knowledge Regarding Triage among 4th Year B.Sc. Nursing Students in a Selected Nursing College, Guwahati, Assam

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ABSTRACT

Triage is done in emergency rooms, disasters and wars, to prioritize care to save maximum number of lives. It helps to identify the urgent needs among patients. Triage knowledge among nurses is important for supervision in emergency department. 1) To assess the pre-test and post-test level of knowledge regarding triage among 4th Year B.Sc. Nursing students. 2) To evaluate the effect of Structured Teaching Programme regarding triage among 4th Year B.Sc. Nursing students. 3) To determine the association between pre-test knowledge scores regarding triage with the selected demographic variables. The research approach and design adopted for this study is quantitative pre-experimental one group pre-test post-test design. The study was conducted at CPMS College of Nursing, PEWS Group of Institutions, Guwahati, Assam among 4th Year B.Sc. Nursing students. 60 nos (Sixty) of 4th Year B.Sc. Nursing students were selected by using non-probability purposive sampling technique. The tools used in the study were demographic pro form a and Self -Structured knowledge questionnaires regarding triage (Total no. of items were 30) were used to assess the knowledge regarding triage. Descriptive and Inferential statistics were used to analyse the data. Results revealed that pre-test mean with standard deviation was 15.23±4.09 and post-test mean with standard deviation was 22.95±2.45 using paired 't' test ($t=15.07$ at $p<0.001$). The result suggests that Structured Teaching Programme was effective in improving the knowledge of students regarding triage. Moreover, it indicates a significant correlation between pre-test knowledge scores and clinical exposure to accident and emergency ward during postings.

Keywords: effect, structured teaching programme, knowledge, triage, 4th Year B.Sc. Nursing students.



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INTRODUCTION

Triage is the process of sorting people based on their need for immediate medical treatment as compared to their chance of benefiting from such care. Triage is done in emergency rooms, disasters, and wars, when limited medical resources must be allocated to maximize the number of survivors. An accurate triage decision helps the patients to receive the emergency care in the most appropriate time. [1] Triage is putting the patient in the right place at the right time to receive the right level of care and the allocation of appropriate resources to meet the patient's medical needs'. This place of the hospital allows for assignment of the care taker to suitable assessment and treatment place. [2] Triage knowledge among nurses is one of the key elements of supervision in emergency department, if it is not carried out at standard level; the outcomes of clinical care of patients and efficiency of emergency departments get compromised. As emergency departments are struggling to cope with overcrowding there is a critical need for a valid, reliable triage acuity rating system in order to sort these incoming patients more rapidly and accurately.[3] The World Health Organization believes that nurses and midwives are frontline workers under stable conditions but more so during situations of emergencies in Hospital settings. In order to contribute to saving lives and promoting health under such difficult conditions, they need to have the adequate knowledge. Hence, the nursing staff must show the ability for critical thinking in demonstrating best standard. [4]

Objectives of the study

1. To assess the pre-test and post-test level of knowledge regarding triage among 4th Year B.Sc. Nursing students
2. To evaluate the effect of Structured Teaching Programme regarding triage among 4th Year B.Sc. Nursing students.
3. To determine the association between pre-test knowledge scores regarding triage with the selected demographic variables.

MATERIALS AND METHODS

A pre-experimental one-group pre-test post-test design was used for the study to accomplish the objectives. 60nos(Sixty) 4th Year B.Sc. Nursing students studying in CPMS College of Nursing, PEWS Group of Institutions participated in the study from 27th January – 2nd February 2024. Formal permission for data collection was taken from the concerned authority of CPMS College of Nursing, PEWS Group of Institutions, Guwahati, Assam before the data collection procedure. Informed consent was taken from the participants and confidentiality was maintained. Pre-test was conducted on the first day by using knowledge questionnaires to assess the knowledge regarding triage among 4th Year B.Sc. Nursing students. Structured Teaching Programmeregarding triage was administered for 45 minutes using pamphlet, chart, handout, power-point presentation and whiteboard. Post test was conducted on the 7th day by using the same knowledge questionnaires. Descriptive and Inferential statistics were used to analyse the data. The frequency and percentage was calculated to assess the knowledge of students.

RESULTS

Section A

Frequency and percentage distribution of demographic variables.

The sample of the study consists of 60 students of 4th Year B.Sc. Nursing of CPMS College of Nursing, PEWS Group of Institutions. Non- probability purposive sampling technique was used. In this section, data collected were analyzed by using descriptive statistics and presented in terms of frequency and percentage distribution. The following are presented in Table 1. The table 1 shows the frequency and percentage distribution of demographic variables of 4th Year B.Sc. Nursing students of selected nursing college. Data analysis shows that out of 60 students, 42(70%) were of the age of 23 years & above and 18(30%) were of the age of 21-22 years. 57 (95%) of the participants were females and 3(5%) were males. 54 students (90%) had exposure to accident and emergency ward during clinical posting and 6





students (10%) had no exposure to accident and emergency ward during clinical posting. 53 students (88%) had previous training on triage and 7 students (12%) had no previous training on triage.

Section B

Description of knowledge of students regarding triage.

This section represents the findings in frequency and percentage distribution related to the pre- test and post-test level of knowledge regarding triage among 4thYear B.Sc. Nursing students. The level of knowledge of 4th Year B.Sc. Nursing students regarding triage was assessed using Self-Structured knowledge questionnaire. Based on the score obtained, the students were arbitrarily categorized as adequate, moderately adequate and inadequate knowledge. The frequency and percentage distribution of pre-test and post-test knowledge are presented on Table 2. **TABLE 2.** depicts the frequency and percentage distribution of level of knowledge score regarding triage among 4th Year B.Sc. Nursing students. Results revealed that in pre-test, majority of the participants i.e., 43 (71.7%) had moderately adequate knowledge, 11 (18.3%) had adequate knowledge and 6(10%) had inadequate knowledge. However, in post-test, majority of the participants i.e., 50 (83.3%) had adequate knowledge and 10(16.7%) had moderately adequate knowledge.

Section C

Effect of Structured Teaching Programme on knowledge regarding triage among 4thYear B.Sc. nursing students

The pre-test and post-test knowledge score obtained by the 4th Year B.Sc. Nursing students regarding triage were tabulated in terms of mean, standard deviation, mean difference and paired *t* value.

S*=Significant at $p<0.001$

NS = Non significant

Table 3 shows that the pre-test mean knowledge score among 4th Year B.Sc. Nursing students was 15.23 ± 4.09 and post-test mean knowledge score was 22.95 ± 2.45 . The calculated '*t*' test value of $t=15.07$ was found to be statistically significant at $p<0.001$ level.

Section D

Association between pre-test knowledge regarding triage with selected demographic variables among 4th Year B.Sc. Nursing students.

This section represents the association of the pre-test level of knowledge regarding triage among 4thYear B.Sc. Nursing students with their selected demographic variables. Chi square was computed to find the significant association between pre-test knowledge regarding triage among 4th Year B.Sc. Nursing students with their selected demographic variables. The data is presented in Table 4.

S*** - Significant at $p<0.001$

NS – Non significant

The table 4 shows that the association of knowledge score regarding emergency triage was significant ($\chi^2=1.25$, $p=0.002$) with the demographic variable exposure to accident and emergency ward during clinical posting at $p<0.001$ level of significance among 4th Year B.Sc. Nursing students and the other demographic variables did not show statistically significant association with pre-test level of knowledge regarding triage among 4th Year B.Sc. Nursing students with their selected demographic variables. Therefore, there is association between the pre-test knowledge regarding triage and exposure to accident and emergency ward during clinical posting.

DISCUSSION

The present study was designed to assess the knowledge regarding triage. The research design adopted for the study was One Group Pre-test Post-test design. Non probability purposive sampling technique was used to select 60 students for the study. The data were analysed statistically and discussed based on the objectives.



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The first objective of the study was to assess the level of knowledge regarding triage among 4th Year B.Sc. Nursing students.

The finding of the present study reveals that in the pre-test, 43(71.7%) i.e., majority of the students had moderately adequate knowledge, 11(18.3%) had adequate knowledge and 6(10%) had inadequate knowledge on triage whereas in the post-test after the Structured Teaching Programme, 50(83.3%) had adequate knowledge and 10(16.7%) had moderately adequate knowledge. The present study is supported by a study of **Khan S, Fatima B(2024)** to assess the knowledge regarding emergency triage among student nurses in selected institutions, Jalandhar. The finding shows that the mean knowledge was 20.16 (± 3.62). As per level of knowledge more than half of the student nurses i.e. 54 (54%) were having average knowledge regarding emergency triage. [5]

The second objective was to assess the effect of Structured Teaching Programme on knowledge regarding triage among 4th Year B.Sc Nursing students.

The pre-test mean score of knowledge among 4th Year B.Sc. Nursing students was 15.23 \pm 4.09 and the post-test mean score of knowledge was 22.95 \pm 2.45. The mean difference score was 7.72. The calculated paired 't' test value of t = 15.07 was found to be statistically significant at p < 0.001 level. This clearly infers that administration of Structured Teaching Programme on knowledge regarding triage was effective in increasing the level of knowledge among 4th Year B.Sc. Nursing students. The present study is supported by a study done by **Supriya R, Gondhuli G, Swastika D (2021)** to assess the effectiveness of structured teaching programme on knowledge and skill regarding management of patients admitted in hospital triage setting among the staff nurses at Era Hospital Lucknow. In the pre-test, among 30 staff nurses, 5(16.66%) were having poor level of knowledge, 22(73.33%) were having average level of knowledge and 3(10%) were good level of knowledge. In the post-test, among 30 staff nurses, 2(6.66%) were having poor level of knowledge, 8(26.66%) were having average level of knowledge and 20(66.66%) were good level of knowledge. [6]

The third objective of the study was to determine the association between pre-test knowledge regarding triage with the selected demographic variables.

The demographic variable exposure to accident and emergency ward during clinical posting ($\chi^2 = 1.25$, $p = 0.002$) has shown statistically significant association with pre-test level of knowledge regarding triage among 4th Year B.Sc. Nursing students at p < 0.001 level and the other demographic variables has not shown statistically significant association with pre-test level of knowledge regarding triage among 4th Year B.Sc. Nursing students. The present study is supported by a study of **Arora A, Thomte H, Swati, Johnson TA, Singh C, Parashar D et al.** to assess the effectiveness of structured teaching program on knowledge regarding triage among the nursing students of selected schools of Greater Noida. According to the study's findings, the majority of pre-test respondents had inadequate knowledge (78.46%), moderate knowledge (20%), good knowledge (1.54%), and very good knowledge (0%). As opposed to this, in the post-test, the maximum percentage of respondents who knew about triage was 38.46%, 32.31% knew it very well, 24.62% knew it averagely and 4.62% knew it poorly. Additionally, it is discovered that, at the p < 0.05 level of significance, there is a significant correlation between nursing students' knowledge scores and a few socio demographic variables, such as whether they have attended disaster management seminars or workshops, are posted in an emergency ward, and are actively involved in managing disaster situations. [7]

CONCLUSION

The present study was conducted to assess the effect of Structured Teaching programme on knowledge regarding triage among 4th Year B.Sc. Nursing students of selected Nursing college of Guwahati, Assam. The findings of the study revealed that the total post-test knowledge score is significantly higher than pre-test as evidenced by t = 15.07 which indicated that STP is effective. It also reveals that there was a significant association between exposure to accident and emergency ward during clinical posting and the pre-test knowledge score regarding triage among 4th Year B.Sc. Nursing students.





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Table 1: Frequency and percentage distribution of demographic variables. n=60

SL.NO	VARIABLES	FREQUENCY(f)	PERCENTAGE(%)
1.	Age in years		
	a) 19-20years	0	0
	b) 21-22years	18	30
	c) 23years and above	42	70
2.	Gender		
	a) Male	3	5
	b) Female	57	95
3.	Exposure to accident and emergency ward during clinical posting.		
	a) Yes	54	90
	b) No	6	10

Table 2: Frequency and percentage distribution of level of knowledge regarding triage among 4th Year B.Sc. Nursing students. n=60

Level of Knowledge score	Pretest		Post Test	
	f	%	f	%
Inadequate knowledge (0-10)	6	10	0	0
Moderately adequate knowledge (11-20)	43	71.7	10	16.7
Adequate knowledge (21-30)	11	18.3	50	83.3





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Table 3: Effect of Structured Teaching Programme on knowledge regarding triage among 4thYear B.Sc. Nursing students.

Comparison of knowledge score	Mean	SD	Mean difference	't' test value	df	'p' value
Pre-test	15.23	±4.09	7.72	15.07	59	<0.0001 ^{S***}
Post-test	22.95	±2.45				

Table 4: Association between pre-test knowledge regarding triage with selected demographic variables among 4thYear B.Sc. Nursing students. n=60

Sl. no	Variables	Pre-test knowledge score			χ ²	df	p value
		Inadequate	Moderately adequate	Adequate			
1.	Age in years a)19-20years b)21-22 years c)23years&above	0 1 5	0 14 29	0 3 8	0.67	4	0.95 ^{NS}
2.	Gender a)Male b)Female	0 6	3 40	0 11	1.25	2	0.53 ^{NS}
3.	Exposure to accident and emergency ward during clinical posting a) Yes b) No	3 3	40 3	11 0	1.25	2	0.002 ^{S***}
4.	Previous training on triage a)Yes b)No	1 5	4 39	2 9	0.83	2	0.66 ^{NS}





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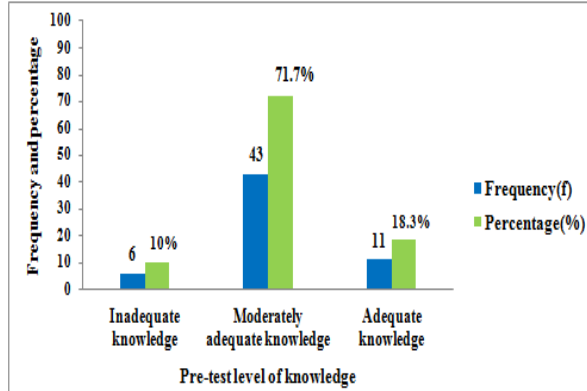


Figure 1: Graph showing the frequency and percentage distribution of pre-test level of knowledge.
n=60

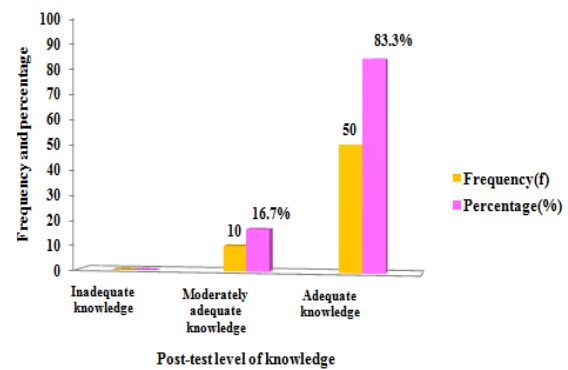


Figure 2: Graph showing the frequency and percentage distribution of post-test level of knowledge.
n=60





Anemia among Women of Northeast India in the Reproductive Age : A Cross - Sectional Analysis of the Trends and Determinant Factors

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ABSTRACT

Anemia is a significant health concern among women aged 15–49 in the northeastern region of India, a region characterized by its unique cultural and geographical features. To assess trends and identify key socio-economic, demographic, and dietary determinants of anemia prevalence among women of reproductive age in Northeast India, using data from NFHS-4 and NFHS-5. This cross-sectional study used NFHS data to assess anemia in women aged 15–49. Bivariate logistic regression calculated crude odds ratios (COR) for each predictor. Multivariate logistic regression, with adjusted odds ratios (AOR) and 95% confidence intervals (CI), controlled for confounders. Statistical significance was set at $p < 0.05$. Women's residence, childbirth, education, wealth, ethnicity, and marital status have a significant impact on the prevalence of anemia. Contradictory findings have been observed among women who never consume fish, vegetables, and aerated drinks. Young (adolescent) and non-pregnant women are found to be most vulnerable, which is a serious concern as it may affect the growth and development of the future generation. Enhancement of women's nutritional education and empowerment may contribute to a great extent to reduce the problem of anemia.

Keywords: Anemia, reproductive-age, women, socio-economic, demographic, diet, logistic regression, Northeast-India



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INTRODUCTION

Anemia is a warning sign of serious illness, and iron deficiency is considered to be the most common anemia and nutritional disorder worldwide[1]. In the era of advanced science and technology, more than a quarter of the world's population is suffering from anemia, and about half of this burden is caused due to deficiency of iron[2]. Although iron deficiency anemia rarely causes death, it has a considerable negative influence on human health and affects a major portion of the population in undeveloped nations, especially women from low and middle-income nations[1,2]. Around 2 billion people worldwide suffer from nutritional anemia, with iron deficiency identified as the primary cause[3]. The prevalence of anemia among non-pregnant women aged 15–49 years has changed a little between 2000 and 2019, from 31% to 30% while the prevalence decreased from 41% to 36% among pregnant women aged 15–49 years [4]. Nutritional deficiency affects individuals all over the world, particularly in developing countries than in developed countries, and females are more likely to be anemic than males where the socio-economic status of people dominates anemia level [4,5]. The National Family Health Survey (2015–2016) found that 53% of women in India were anemic, indicating the country's ongoing high anemia rate [6] In India, the issue of iron deficiency anemia continues to be a serious problem, with more than 15 states having a high prevalence of anemia (>55%), primarily in socially disadvantaged groups, between 2019 and 2021. Most Indian states (eastern, northeastern, and central) have experienced that reproductive women are more susceptible to anemia due to low nutritional intake. Anemia affects northern women more than southern women, and the southern states of India are in much better position than the other states [7]. The high prevalence of anemia among women in India, particularly in the North-East region, is a significant health problem that affects maternal mortality rates[8]. In northeast India, the prevalence of anemia varies within the region and within the states along with their changing socio-economic characteristics, and women are adversely affected by anemia over time [8]. About 40% of women had anemia, which is a significant frequency among women in the northeastern region of India [9]. Additionally, the prevalence of anemia among pregnant women in a rural farming population in Northeast India is almost 90%, which is higher than the national average of 65-70% [10]. As the prior research has not yet provided a clear explanation of the factors that increase the prevalence of anemia in North-East Indian reproductive women [8,9,10,19]. Therefore, with the sharp rise of anemia noticed in the northeastern region of India, this study aimed to assess the trend and identify the significant determinants responsible for the prevalence of anemia with respect to socio-economic, demographic, and dietary factors, including all women of reproductive age in Northeast India, by using NFHS-4 and NFHS-5.

MATERIALS AND METHODS:

Data Source

The present study utilizes the data on anemia from the two rounds of the National Family Health Survey (NFHS), which were carried out by the Ministry of Health and Family Welfare of the Government of India, with the International Institute for Population Science acting as the nodal organization.¹² It uses secondary data from NFHS-4 (2015–2016) and NFHS-5 (2019–2021) on anemia among women in the northeastern states (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim) of India, with a sample size of 100435 in NFHS-5 and 96352 in NFHS-4 who are between the ages of 15 and 49.

Variable Measurement

The dependent variable is classified dichotomously as 'anemic' and 'non-anemic'. The socio-economic factors include place of residence, educational level, religion, ethnicity, wealth status, children ever born, and pregnancy status of women. Demographic factors include the age and marital status of women. Among dietary factors, the frequency of diet intake for various types of nutritional foods, such as pulses or beans, fruits, eggs, vegetables, fish, fried foods, chicken or meat, as well as the consumption of milk or curd and aerated beverages, has been included in the analysis.

Data Analysis

Data were entered and analyzed using SPSS Version 26 for Windows. Descriptive statistics are presented as percentages, where appropriate. The odds ratio (OR) is computed to determine the association between outcome and



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predictor variables. Bivariate logistic regression analysis is initially conducted to examine the individual association between each predictor variable and anemia among women aged 15–49. This is followed by multivariate logistic regression analysis to identify trends in anemia while controlling for potential confounding variables. Findings from both NFHS surveys are presented as crude odds ratios (COR) and adjusted odds ratios (AOR) with 95% confidence intervals (CI). The AOR measures the strength of statistical associations, with a p-value <0.05 indicating statistical significance.

RESULTS

Trends of anemia

The trend of anemia among northeastern women has significantly increased from 38.7% in NFHS-4 to 50.1% in NFHS-5. This cross-sectional study has shown an overall increment of 11.4% (Fig. 1). With respect to different respondents' characteristics, the trend of anemia has shown different variations. Anemia has increased among women in all age groups. Age groups 15–19 and 40–44 have witnessed the highest (15.90%) and the lowest (9.10%) rates, respectively. Increment of anemia in women is slightly more in rural areas (10.90%) as compared to urban areas (10.50%), while a huge difference in increment is seen among non-pregnant anemic women (11.8%) and pregnant anemic women (3.90%). Among uneducated women, the trend of anemia has risen from 44.5% in 2015–16 to 53.9% in 2019–21. In all marital statuses—never in union, married, widowed, divorced, or separated women, the level of anemia showed an increase of above 10%. Anemia has risen by 9.20% among women who belong to the poorest wealth index. Muslim women are found to be more anemic, with an increase of 17.50%, followed by Hindu women at 17.30%. Although both in NFHS-4 and NFHS-5 the highest percentage of anemia is seen among women who don't know their ethnicity (51.0% in 2015-16 and 65.7% in 2019-21), but increment is seen more among those who belong to caste (17.70%). Also, an equal increment of 9% is seen among women with three, four or more child. As per the diet pattern, a high increment in anemia is seen among northeastern women who daily consume fried foods (15.90%) and aerated drinks (12.70%). Women's daily consumption of milk or curd has increased by the least amount, 9.20%. An equal increment of 14.80% is seen among women who never consume chicken or meat and who occasionally eat vegetables. Similarly, a 12.90% rise has been observed in women who never eat fruits and eggs. Daily consumption of fish (15.80%) and pluses or beans (13.10%) by women has witnessed substantial growth in anemia, causing inconsistent results (Table 1).

Factors associated with anemia among women

Bivariate Analysis: In NFHS-5, women's age, place of residence, education level, religion, wealth index, marital status, pregnancy status, consumption of milk or curd, fruits, fish, chicken or meat and aerated drinks are found to be significantly associated with anemia at $P < 0.05$, whereas in NFHS-4, women's place of residence, education level, religion, wealth index, children ever born, pregnancy status, marital status, and consumption of fruits are found to be significantly associated with anemia at $P < 0.05$ (Table 2). Multivariable Analysis: After adjusting for confounders, in NFHS-5, mostly women's age, place of residence, religion, ethnicity, wealth index, marital status, and pregnancy status remain significantly associated with anemia at $p < 0.05$, whereas in NFHS-4, women's place of residence, religion, ethnicity, number of children born, wealth index, and pregnancy status remain significantly associated with anemia at $p < 0.05$. In NFHS-5, anemia is more common among women from rural areas as compared to urban areas; the risk of anemia among rural women is 1.23 times higher (AOR=1.23, 95%CI=1.19-1.28), whereas the risk of anemia among pregnant women is found to be lower than that of non-pregnant women (AOR=0.71, 95%CI=0.66-0.76). Women aged 20-24 years (AOR=0.85), 25-29 years (AOR=0.77), 30-34 years (AOR=0.71), 35-39 years (AOR=0.71), 40-44 years (AOR=0.69) and 45-49 years (AOR=0.67) are less susceptible to anemia than women aged 15-19 years. Muslim women (AOR=0.69), Christian women (AOR=0.55) and women belonging to other religions (AOR=0.57) are less likely to be anemic than Hindu women. Women with secondary education have 0.91 times (AOR=0.91, 95%CI=0.87-0.95) and those with higher education have 0.87 times (AOR=0.87, 95%CI=0.82-0.92) have lower odds of being anemic when compared to those with no education. Similarly, women having only two children (AOR=1.12, 95%CI=1.05-1.19) and four or more children (AOR=1.21, 95%CI=1.13-1.29) are more likely to be affected by anemia than women without



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children. When compared with women who are never in union, married women are 1.08 times (AOR=1.08, 95%CI=1.02-1.15) and women who are widowed/divorced/separated are 1.18 times (AOR=1.18, 95%CI=1.09-1.29) more likely to suffer from anemia. Women belonging to tribe (AOR=0.83) have less likelihood of being anemic, while those women belonging to no caste/tribe (AOR=1.09) and those who do not know their ethnicity (AOR=1.39) are more susceptible to anemia when compared with caste. The chance of having anemia are less among poorer women (AOR=0.87), middle-class women (AOR=0.81), richer women (AOR=0.80) and richest women (AOR=0.80) in comparison to the poorest women. As per dietary pattern when compared with never consumption of food, women who consume fried foods daily (AOR=1.11), green leafy vegetables occasionally (AOR=1.42), fish weekly (AOR=1.24) are more susceptible to anemia while the risk of anemia is low among those who consume chicken or meat daily (AOR=0.79) and weekly (AOR=0.87), milk or curd daily (AOR=0.88). Contrasting results have been found where fruit consumption has no significant impact on the occurrence of anemia.

Consumption of aerated drinks weekly (AOR=0.93) and daily (AOR=0.93), occasional consumption of pulses or beans (AOR=0.85) and eggs (AOR=0.89) are found to be less anemic. When compared to NFHS-5, in NFHS-4, similar high prevalence of anemia is seen among women belonging to rural areas, Hindu religion, poorest wealth index, and non-pregnant women. While low prevalence of anemia is seen among women who have never in union. Additionally, women's education, consumption of fruits and aerated drinks showed similar result as in NFHS-5. In NFHS-4, changes are seen among women aged 25–29 years (AOR=0.91), 30–34 years (AOR=0.86), 35–39 years (AOR=0.86), 40–44 years (AOR=0.89) and 45–49 years (AOR=0.82) who are found to be less susceptible to anemia than women aged 15–19 years. While women aged 20–24 showed insignificant result. All women having one child (AOR=1.09), two child (AOR=1.14), three child (AOR=1.11) and four or more child (AOR=1.16) are more prone to experience anemia. Similarly, all women belonging to tribe (AOR=1.05), no caste/tribe (AOR=1.09), and those who do not know their ethnicity (AOR=1.33) are more susceptible to anemia. When compared with never consumption of foods, women who weekly (AOR=0.85) and occasionally (AOR=0.78) consume pulses or beans, daily consume green leafy vegetables (AOR=0.77), occasionally consume fish (AOR=0.89) are less likely to be affected by anemia. Although consumption of milk or curd daily (AOR=0.95) have lower likelihood of anemia but consuming it weekly (AOR=1.07) increases the chances of developing anemia. Moreover, consumption of eggs, chicken or meat, and fried food showed a negligible impact on the prevalence of anemia in NFHS-4 (Table 2). Abbreviation: AOR, Adjusted Odds Ratio; COR, Crude Odds Ratio; *Statistically significant ($p < 0.05$)

DISCUSSION

Anemia is a significant health concern among reproductive women in Northeast India.⁹ Therefore, the aim of this study is to determine the trend of anemia prevalence and the influence of a wide range of socio-economic, demographic, and dietary factors on the prevalence of anemia in reproductive-age women in northeast India. Among the various socio-economic factors that are explored in this study, few are found to have direct association, whereas others illustrate an inverse relationship. Two in every five women had anemia, and the prevalence of anemia was high among women residing in rural areas, having no education, and belonging to low-income families, which is similar to the findings of the present study [9]. Studies have revealed similar findings in national contexts as well [3, 7, 14, 20]. Highly educated women are more aware of anemia and take the necessary steps to prevent it by consuming foods high in iron and taking iron supplements. Rural women experience more suffering as a result of their lower purchasing ability to meet their basic needs. Hindu women in the northeast have the maximum risk of being anemic, while Christian women continue to be in a privileged position [3]. According to this study, pregnant women have lower level of anemia than non-pregnant women, which might occur as a result of pregnant women receiving additional care, iron-rich foods, and supplements. While, previous study carried out in northeast India revealed high prevalence of anemia among pregnant women [8]. In India, pregnant women experience anemia more severely than non-pregnant women do, but it is also evident that non-pregnant women aged less than 25 years are mostly affected by anemia [3]. In northeastern India, women belonging to Scheduled Castes and Scheduled Tribes are seen to be primarily affected by anemia [9]. While women who don't know their ethnicity have high prevalence



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of anemia, according to the current study. Insufficient healthy food consumption increases the prevalence of anemia among tribal populations in north-eastern India [11,19,21]. Additionally, this study discovered that anemia is more common in women who have had two or more children. Sharif *et al* [7]. found similar results in a cross-sectional study conducted in India. The reason might be that repetitive pregnancy reduces Hb in blood and increases the risk of anemia significantly. Among the demographic factors, the present study found that young (adolescent) women aged 15-19 are more likely to suffer from anemia. Contrary to this, a previous study done in northeast India inferred that women aged 35–49 are more likely to develop anemia [9]. Anemia is also seen to be adversely affected by women's marital status in our study. As reported by Barman [18] the EAG states of India showed similar results where widowed and no longer living-together women are more likely to suffer from anemia, followed by married and other women. This might be due to improper diet, which is causing nutritional deficiencies in their loneliness. The third most significant factor in the current study is dietary consumption. Daily consumption of milk or curd and chicken or meat decreases the risk of anemia. This study is comparable to the prior one.¹⁵ Blood hemoglobin level is significantly correlated with intake of milk and yogurt [13]. Dietary pattern with high intakes of fried foods significantly increases the risk of anemia. This contradicts a previous study conducted in northeast India, where the consumption of fried foods showed no significant connection [9]. Never consumption of aerated beverages increases the risk of anemia, which contradicts the outcome that consumption of fizzy drinks leads to anemia [16]. A similar conflicting outcome with respect to dietary intake of vegetables and fish is seen in our study, where women who never consume green leafy vegetables and fish are found to be less anemic. Vegetarian diets are associated with a higher risk of developing iron-deficiency anemia, and daily consumption of fish is associated with lower odds of being anemic among Indian women [15]. Anemia is more likely to occur in northeastern women who never consume eggs and pulses or beans. Daily consumption of eggs and pulses or beans are found to be significantly associated with a lower risk of anemia among women in India.[15,17] In our study consumption of fruits is found to be statistically insignificant with anemia. Although fruits are rich source of iron, which improves our hemoglobin levels but studies conducted in India have found that consumption of fruits by women has no statistically significant impact on anemia status.[15]

CONCLUSION AND RECOMMENDATION

With the aid of present study, we could comprehend better relationship between socioeconomic, demographic, and dietary factors and the prevalence of anemia in women in northeast India. Multivariable analysis reveals that young (adolescent) women, rural residents, Hindu religion, uneducated, higher-order births, poor wealth index, non-pregnant women, women who don't know their ethnicity, widowed, divorced, or separated women, along with inadequate dietary intake, are among the major determining factors behind the high prevalence of anemia. There have been some conflicting findings, where women who never consume vegetables, fish are found to be less anemic, and those who never consume aerated drinks are found to be more anemic. Awareness regarding the cause and spread of anemia must be created, and economic health facilities must be imposed. Additionally, nutrition education program must be promoted to focus on the development of healthy eating habits and the consumption of iron-rich foods. Diversity in the region leads to the need for more in-depth research among the women of northeastern states individually to better understand and combat the problem of the high prevalence of anemia among women aged 15–49 across the northeast region.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.





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Table 1: The percentage trend of anemia among reproductive-age women in Northeast India was recorded in NFHS-4 (N=96,352) and NFHS-5 (N=100,435).

Variables	NFHS-4 (2015-2016)	NFHS-5 (2019-2021)	(NFHS-5 - NFHS-4)
Age in years			
15-19	37.4	53.3	15.90
20-24	38.7	50.7	12.00
25-29	38.7	48.9	10.20
30-34	38.2	48.8	10.60
35-39	39.2	50.0	10.80
40-44	40.3	49.4	9.10
45-49	39.4	49.6	10.20
Type of place of residence			
Urban	33.1	43.6	10.50
Rural	40.8	51.7	10.90
Highest educational level			
No education	44.5	53.9	9.40
Primary	41.8	52.6	10.80
Secondary	37.2	49.8	12.60
Higher	32.2	43.2	11.00
Religion			
Hindu	44.3	61.6	17.30
Muslim	40.6	58.1	17.50
Christian	33.8	39.3	5.50
Other	36.7	40.9	4.20
Ethnicity			
Caste	41.8	59.5	17.70
Tribe	35.8	41.8	6.00
No caste/ tribe	42.7	59.4	16.70
Don't know	51.0	65.7	14.70
Wealth index combined			
Poorest	46.4	55.6	9.20
Poorer	41.5	50.5	9.00
Middle	37.7	47.7	10.00
Richer	34.5	44.2	9.70
Richest	31.3	42.1	10.80
Total no of children born			
No child	35.4	48.3	12.90
One child	40.2	52.1	11.90
Two child	40.8	52.6	11.80
Three child	39.6	48.6	9.00
Four or more child	40.7	49.7	9.00
Currently pregnant			
No or unsure	38.8	50.6	11.80
Yes	37.2	41.1	3.90
Current marital status			





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Never in union	34.8	48.0	13.20
Married	40.2	50.9	10.70
Widowed/Divorced/Separated	40.6	51.1	10.50
Frequency takes milk or curd			
Never	37.5	47.3	9.80
Daily	36.9	46.1	9.20
Weekly	41.2	52.1	10.90
Occasionally	38.6	51.9	13.30
Frequency eats pulses/beans			
Never	42.7	50.2	7.50
Daily	43.6	56.7	13.10
Weekly	37.2	46.9	9.70
Occasionally	34.1	43.2	9.10
Frequency eats vegetables			
Never	43.9	49.3	5.40
Daily	38.1	47.1	9.00
Weekly	39.9	53.7	13.80
Occasionally	40.2	55.0	14.80
Frequency eats fruits			
Never	42.6	55.5	12.90
Daily	37.7	47.0	9.30
Weekly	38.6	50.2	11.60
Occasionally	38.9	50.5	11.60
Frequency eats eggs			
Never	40.2	53.1	12.90
Daily	38.4	49.4	11.00
Weekly	39.6	52.0	12.40
Occasionally	37.5	47.1	9.60
Frequency eats fish			
Never	39.0	47.0	8.00
Daily	38.4	54.2	15.80
Weekly	41.3	54.1	12.80
Occasionally	35.6	43.3	7.70
Frequency eats chicken/meat			
Never	40.7	55.5	14.80
Daily	34.1	46.1	12.00
Weekly	38.6	50.3	11.70
Occasionally	39.0	50.0	11.00
Frequency eats fried food			
Never	40.3	51.9	11.60
Daily	38.7	54.6	15.90
Weekly	39.1	49.2	10.10
Occasionally	38.2	49.5	11.30
Frequency eats aerated drinks			
Never	41.3	49.9	8.60
Daily	41.0	53.7	12.70
Weekly	37.6	48.8	11.20
Occasionally	37.9	47.9	10.00





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TOTAL	38.7	50.1	11.4
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Table 2. Factors associated with anemia among reproductive women of northeast India, 2015-16 and 2019-21.

VARIABLES	NFHS-4		NFHS-5	
	COR(95%CI)	AOR(95%CI)	COR(95%CI)	AOR(95%CI)
Age in Years				
15-19	Reference	Reference	Reference	Reference
20-24	1.06(1.01-1.11)*	0.97(0.92-1.02)	0.90(0.86-0.94)*	0.85(0.81-0.89)*
25-29	1.06(1.01-1.10)*	0.91(0.86-0.96)*	0.84(0.80-0.87)*	0.77(0.73-0.81)*
30-34	1.04(0.99-1.09)	0.86(0.81-0.91)*	0.84(0.79-0.87)*	0.71(0.67-0.75)*
35-39	1.08(1.03-1.13)*	0.86(0.81-0.92)*	0.87(0.84-0.92)*	0.71(0.67-0.76)*
40-44	1.13(1.07-1.19)*	0.89(0.83-0.95)*	0.85(0.81-0.89)*	0.69(0.64-0.73)*
45-49	1.09(1.03-1.14)*	0.82(0.77-0.88)*	0.86(0.82-0.91)*	0.67(0.63-0.72)*
Type of place of residence				
Urban	Reference	Reference	Reference	Reference
Rural	1.39(1.35-1.44)*	1.17(1.13-1.21)*	1.38(1.34-1.43)*	1.23(1.19-1.28)*
Highest educational level				
No education	Reference	Reference	Reference	Reference
Primary	0.89(0.86-0.94)*	0.96(0.92-1.01)	0.95(0.91-0.99)*	0.99(0.94-1.04)
Secondary	0.74(0.71-0.77)*	0.86(0.83-0.89)*	0.85(0.82-0.87)*	0.91(0.87-0.95)*
Higher	0.59(0.56-0.62)*	0.79(0.75-0.85)*	0.65(0.62-0.68)*	0.87(0.82-0.92)*
Religion				
Hindu	Reference	Reference	Reference	Reference
Muslim	0.86(0.83-0.90)*	0.74(0.70-0.78)*	0.86(0.83-0.89)*	0.69(0.66-0.74)*
Christian	0.64(0.63-0.66)*	0.73(0.69-0.77)*	0.40(0.39-0.42)*	0.55(0.52-0.57)*
Other	0.73(0.69-0.77)*	0.78(0.74-0.83)*	0.43(0.41-0.45)*	0.57(0.54-0.60)*
Ethnicity				
Caste	Reference	Reference	Reference	Reference
Tribe	0.78(0.76-0.80)*	1.05(1.00-1.09)*	0.48(0.47-0.50)*	0.83(0.79-0.87)*
No caste/ tribe	1.04(0.99-1.09)	1.09(1.03-1.15)*	0.99(0.95-1.04)	1.09(1.03-1.15)*
Don't know	1.45(1.25-1.68)*	1.33(1.15-1.55)*	1.31(1.08-1.58)*	1.39(1.15-1.69)*
Wealth index combined				
Poorest	Reference	Reference	Reference	Reference
Poorer	0.82(0.79-0.86)*	0.86(0.82-0.89)*	0.81(0.78-0.84)*	0.87(0.84-0.89)*
Middle	0.69(0.67-0.73)*	0.79(0.75-0.83)*	0.73(0.70-0.75)*	0.84(0.81-0.88)*
Richer	0.61(0.58-0.64)*	0.74(0.70-0.78)*	0.63(0.61-0.66)*	0.80(0.76-0.84)*
Richest	0.53(0.49-0.56)*	0.71(0.66-0.75)*	0.58(0.55-0.62)*	0.80(0.75-0.87)*
Total no of children ever born				
No child	Reference	Reference	Reference	Reference
One child	1.23(1.18-1.27)*	1.09(1.03-1.16)*	1.16(1.12-1.21)*	1.06(0.99-1.12)
Two child	1.26(1.21-1.30)*	1.14(1.07-1.21)*	1.18(1.15-1.22)*	1.12(1.05-1.19)*
Three child	1.19(1.15-1.24)*	1.11(1.04-1.19)*	1.01(0.97-1.06)	1.06(0.99-1.13)
Four or more child	1.25(1.20-1.30)*	1.16(1.09-1.24)*	1.06(1.02-1.09)*	1.21(1.13-1.29)*





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Currently pregnant				
No or unsure	Reference	Reference	Reference	Reference
Yes	0.94(0.88-0.99)*	0.92(0.86-0.98)*	0.68(0.64-0.73)*	0.71(0.66-0.76)*
Current marital status				
Never in union	Reference	Reference	Reference	Reference
Married	1.26(1.22-1.29)*	1.09(1.03-1.16)*	1.12(1.09-1.15)*	1.08(1.02-1.15)*
Widowed/Divorced/Separated	1.28(1.20-1.36)*	1.19(1.09-1.29)*	1.13(1.06-1.20)*	1.18(1.09-1.29)*
Frequency takes milk or curd				
Never	Reference	Reference	Reference	Reference
Daily	0.98(0.94-1.02)	0.95(0.90-0.99)*	0.95(0.91-0.99)*	0.88(0.84-0.92)*
Weekly	1.17(1.12-1.22)*	1.07(1.02-1.12)*	1.21(1.16-1.26)*	0.99(0.95-1.04)
Occasionally	1.05(1.01-1.09)*	1.03(0.99-1.08)	1.20(1.15-1.26)*	1.03(0.98-1.07)
Frequency eats pulses or beans				
Never	Reference	Reference	Reference	Reference
Daily	1.04(0.90-1.19)	1.08(0.93-1.24)	1.30(1.13-1.49)*	1.08(0.93-1.24)
Weekly	0.79(0.69-0.91)*	0.85(0.73-0.98)*	0.87(0.76-1.01)	0.88(0.76-1.01)
Occasionally	0.69(0.60-0.79)*	0.78(0.67-0.89)*	0.76(0.65-0.87)*	0.85(0.73-0.99)*
Frequency eats green leafy vegetable				
Never	Reference	Reference	Reference	Reference
Daily	0.79(0.61-1.02)	0.77(0.59-0.99)*	0.92(0.72-1.16)	1.01(0.79-1.29)
Weekly	0.85(0.66-1.09)	0.84(0.65-1.09)	1.19(0.94-1.52)	1.25(0.98-1.61)
Occasionally	0.86(0.66-1.12)	0.91(0.69-1.19)	1.26(0.99-1.61)	1.42(1.10-1.82)*
Frequency eats fruits				
Never	Reference	Reference	Reference	Reference
Daily	0.82(0.73-0.91)*	0.99(0.89-1.12)	0.71(0.63-0.81)*	0.93(0.82-1.06)
Weekly	0.85(0.76-0.94)*	0.95(0.85-1.05)	0.81(0.72-0.91)*	0.94(0.83-1.07)
Occasionally	0.86(0.78-0.95)*	0.96(0.86-1.07)	0.82(0.73-0.92)*	0.96(0.85-1.09)
Frequency eats eggs				
Never	Reference	Reference	Reference	Reference
Daily	0.93(0.85-1.02)	1.04(0.94-1.16)	0.86(0.78-0.95)*	1.03(0.93-1.15)
Weekly	0.98(0.90-1.05)	0.98(0.89-1.07)	0.96(0.88-1.04)	0.99(0.90-1.09)
Occasionally	0.89(0.83-0.96)*	0.95(0.87-1.05)	0.78(0.72-0.86)*	0.89(0.81-0.98)*
Frequency eats fish				
Never	Reference	Reference	Reference	Reference
Daily	0.98(0.89-1.08)	0.90(0.81-1.01)	1.33(1.21-1.47)*	1.12(0.99-1.26)
Weekly	1.10(1.01-1.20)*	1.02(0.92-1.13)	1.33(1.21-1.46)*	1.24(1.11-1.38)*
Occasionally	0.87(0.79-0.95)*	0.89(0.81-0.99)*	0.86(0.78-0.95)*	1.02(0.91-1.13)
Frequency eats chicken or meat				
Never	Reference	Reference	Reference	Reference
Daily	0.75(0.68-0.84)*	0.89(0.78-1.00)	0.68(0.62-0.76)*	0.79(0.71-0.90)*
Weekly	0.92(0.85-0.99)*	0.98(0.89-1.08)	0.81(0.74-0.88)*	0.87(0.78-0.96)*
Occasionally	0.93(0.86-1.01)	1.00(0.91-1.10)	0.80(0.73-0.87)*	0.93(0.84-1.03)
Frequency eats fried food				





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Never	Reference	Reference	Reference	Reference
Daily	0.94(0.87-1.01)	1.01(0.94-1.09)	1.16(1.07-1.26)*	1.11(1.02-1.21)*
Weekly	0.95(0.88-1.02)	1.03(0.95-1.12)	0.95(0.88-1.04)	0.95(0.87-1.04)
Occasionally	0.92(0.85-0.99)*	1.04(0.96-1.13)	0.93(0.86-1.00)	0.96(0.88-1.05)
Frequency takes aerated drinks				
Never	Reference	Reference	Reference	Reference
Daily	0.99(0.92-1.06)	1.05(0.97-1.13)	1.12(1.05-1.19)*	0.96(0.89-1.02)
Weekly	0.86(0.82-0.89)*	0.94(0.89-0.98)*	0.89(0.86-0.94)*	0.93(0.89-0.98)*
Occasionally	0.87(0.84-0.89)*	0.95(0.91-0.98)*	0.91(0.88-0.94)*	0.93(0.89-0.97)*

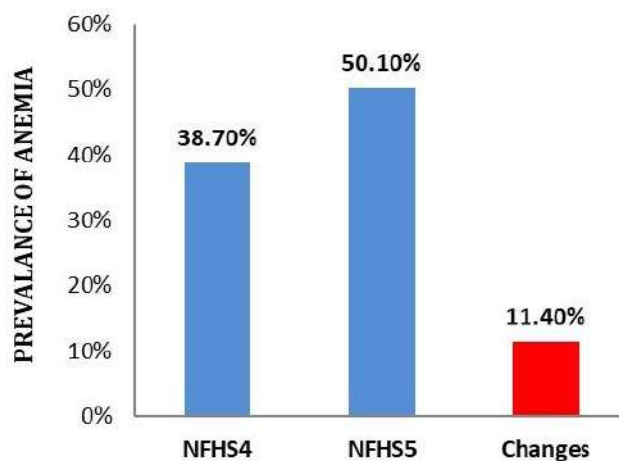


Fig1. The trends of anemia among northeast women, NFHS-4(2015-16) and NFHS-5 (2019-2021).





Modelling and Forecasting Rice Production Volatility: A Threshold Auto Regression (TAR) Approach for Predictive Insights

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ABSTRACT

The present study develops a predictive model for the rice crop production of India based on yield and area under irrigation using Threshold Auto Regression (TAR). The objective of this paper has been on finding nonlinear patterns and thresholds existing within rice production data to understand the volatility in production. By using data of India rice production from the period 1950-2022, TAR model with R-squared value of 0.9937, very high value of predictability and depicts more than 99% variation in rice production data. These error metrics also give testimony to the reliability of this model. The RMSE stands at 2.41, MAE is 1.62, and MAPE is 2.67%. These error metrics point towards slight deviation between the values predicted and the actual results, giving evidence of the fact that the TAR model surely captures the underlying pattern in data. This research will therefore provide a normative-based tool for all stakeholders to forecast potential changes in rice production and thus inform food security planning.

Keywords: Rice production, Threshold Auto Regression (TAR), Predictive modelling, Agricultural forecasting, India

INTRODUCTION

For millions of people around the world, especially in India, the largest rice-producing country, rice production is among the most important lifelines and outlets for food security. The large agricultural landscape itself and the



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variability of the climate conditions are indeed hard to predict when it comes to rice yield. Yield per hectare and area irrigated have been identified as crucial variables determining productivity in rice production (Ansarifar et al., 2021a). The yield is represented as the production efficiency per unit area, while the area under irrigation represents the investment in resources for production. However, the total production often goes hand-in-hand with these parameters in a non-linear, dynamic way, thus posing the need for advanced predictive models that can capture such complexity (Lan & Dinh, n.d.). In this work, we employ an advanced econometric technique peculiarly suited for data with threshold effects and regime shifts—namely, the Threshold Auto Regression (TAR) model to analyze and forecast rice production based on these critical parameters. Our analysis employs historical data from 1950 to 2022 to cover over half a century and permit a longer-run examination of trends and volatility in rice production. From the descriptive statistics, considerable variation in rice output over the years is revealed with high standard deviations and noticeable skewness, which requires accurate predictions for agricultural planning purposes (Satpathi et al., 2023). Correlation analysis in figures 5 and 6 shows a very high positive association between rice production, yield, and irrigation, which is why those parameters were chosen for the TAR model. Model validation against error metrics such as R-squared, RMSE, and MAPE confirms the model as reliable in explaining over 99% variance in rice production (Broms et al., 2023). This would enable policymakers and other stakeholders to derive valuable insight into policy considerations by providing a strong framework for forecasting production and identification of imperatives of targeted strategies toward stabilization with environmentally and economically changing conditions. Our study provides a detailed and evidence-based tool that is supportive of sustainable agriculture and strengthens food security planning in India (Ansarifar et al., 2021b).

LITERATURE REVIEW

Rice yield forecasting is important for the reason of providing food security and the need for rational use of resources. Various statistical methods have been attempted in rice yield forecasting with varying degrees of accuracy and usability (Kern et al., 2018). Regression models, especially the multiple linear regression (MLR), have been one of the most widely used tools that allow one to establish relations between climatic variables, such as rainfall or temperature, and crop yields. The research has shown that such models work perfectly for locations where weather conditions have good predictability and, therefore, the data of past values can become a relatively good basis for forecasting (Masrur Ahmed et al., 2022). MLR often fails to deal with nonlinear relationships and interactions between two or more influencing factors. Another very powerful tool applied in the process of forecasting rice production has been time series analysis, which particularly gives good results for areas where seasonal trends are quite strong. Others include ARIMA and SARIMA, especially in picking the natural seasonal oscillations in rice output. It involves the analysis of past data to predict yields yet unrecorded; hence these are very applicable in areas whose agricultural cycles repeatable and reliable. Moreover, studies combined time series models with climatic factors such as temperature and rainfall (Mishra et al., 2020). This is usually more accurate because past trends can be offset by environmental conditions to produce a better estimate. The accuracy of such models deteriorates in fluctuating or rapidly shifting climates (Felkner et al., 2009). The flexibility of such models to adapt to stationary or non-stationary patterns and to provide more solutions in forecasting is much augmented. For example, it was shown in Indonesia that the combination of fuzzy logic with Markov Chains was an improvement for the forecast, especially in regions with varying weather conditions, however unpredicted (Montesinos-Lopez et al., 2021). Recently, the application of machine learning techniques such as Random Forest (RF), Random Trees (RT), Naïve Bayes (NB), and Artificial Neural Networks (ANN) is considered as the new frontier in rice production forecasting (Prakash Jorvekar et al., 2024a). The models are particularly powerful since they enable the processing of large datasets while simultaneously learning complex relationships and adapting to non-linear interactions among multiple variables. Recent studies have demonstrated how machine learning models, mainly RF and RT, significantly outperform traditional methods in terms of achieving higher prediction accuracies (Kim et al., 2023). For example, it will be proved that a machine learning model can make up to 100% predictions regarding the yields of rice using climatic and environmental data. These are new promising ways of developing methodologies in rice forecasting, but they require considerable





amounts of data as well as considerable computing resources. This is critical for sparse or irregular regions with limited data (Dharmaraja et al., 2020).

METHODOLOGY

The study employs a Threshold Auto Regression (TAR) model to analyze the non-linear relationships between rice production, yield (Rahman et al., 2021), and area under irrigation in India. Historical data from 1950 to 2022 is used to identify yield thresholds, segment the dataset, and estimate regime-specific parameters.

The Threshold Auto Regression (TAR) model segments data into distinct regimes based on a threshold variable, applying different linear regression equations to each regime. Below is a step-by-step derivation and parameter estimation process for a TAR model (Prakash Jorvekar et al., 2024a).

$$y_t = \begin{cases} \alpha_1 + \beta_1 X_t + \gamma_1 Z_t + \varepsilon_t, & \text{if } X_t \leq \tau \\ \alpha_2 + \beta_2 X_t + \gamma_2 Z_t + \varepsilon_t, & \text{if } X_t > \tau \end{cases} \quad (1)$$

Here, y_t is Dependent Variable, X_t is Predictor 1, Z_t is Predictor 2, ε_t is Residual, τ is Threshold Value and α, β, γ are constants

Then the OLS estimates of the both regression line for Regime 1 & 2 are

For Regime 1: for $X_t \leq \tau$, β_1 and γ_1 are

The regression Equation of regime 1 is,

$$\alpha_1 + \beta_1 X_t + \gamma_1 Z_t + \varepsilon_t, \text{ if } X_t \leq \tau \quad (2)$$

the OLS estimates of the equation become

$$\begin{bmatrix} \sum X_{t1}^2 & \sum X_{t1}Z_{t1} \\ \sum X_{t1}Z_{t1} & \sum Z_{t1}^2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \gamma_1 \end{bmatrix} = \begin{bmatrix} \sum X_{t1}Y_{t1} \\ \sum Z_{t1}Y_{t1} \end{bmatrix}$$

For Regime 2: for $X_t > \tau$, β_2 and γ_2 are

The regression Equation of regime 2 is,

$$\alpha_2 + \beta_2 X_t + \gamma_2 Z_t + \varepsilon_t, \text{ if } X_t > \tau \quad (3)$$

the OLS estimates of the equation become,

$$\begin{bmatrix} \sum X_{t2}^2 & \sum X_{t2}Z_{t2} \\ \sum X_{t2}Z_{t2} & \sum Z_{t2}^2 \end{bmatrix} \begin{bmatrix} \beta_2 \\ \gamma_2 \end{bmatrix} = \begin{bmatrix} \sum X_{t2}Y_{t2} \\ \sum Z_{t2}Y_{t2} \end{bmatrix}$$

The developed rice production model was evaluated in terms of predictive performance using the metrics RMSE, MAE, MAPE, and sMAPE. While RMSE focuses on larger errors and is considered to be a measure of the model's precision, MAE provides the average absolute error, an easy and easy accuracy measure. MAPE conveys error in percentage form of actual values; one of its advantages is the possibility of cross-scale comparisons, but requires considering both actual and predicted values symmetrically to avoid the imbalance in its evaluation. Therefore, these metrics evaluate the model's accuracy and reliability holistically (Lee et al., n.d.).

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_t - \hat{Y}_t)^2} \quad (4)$$

$$MAE = \frac{1}{n} \sum_{i=1}^n |Y_t - \hat{Y}_t| \quad (5)$$

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right| * 100 \quad (6)$$

$$sMAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{Y_t - \hat{Y}_t}{\frac{|Y_t| + |\hat{Y}_t|}{2}} \right| * 100 \quad (7)$$

RESULTS AND DISCUSSIONS

Data sources on rice production, yield, and area under irrigation for this paper are pulled from World Bank's WDI over the history spanning 1950 to 2022. Descriptive statistics for rice production, yield, and area under irrigation give an idea about the distribution of data in the dataset, the central tendencies of the data, and the variability in the data (Prakash Jorvekar et al., 2024b). The mean of production, yield, and area under irrigation is 65.85 million tonnes,





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1605.59 kg/hectare, and 43.91 million hectares, respectively, which have been the typical levels of all these attributes during the years that have been used for analysis. With standard deviations of 30.69 for production, 635.56 for yield, and 7.05 for area under irrigation, the spread around the mean is huge, while the fluctuation in production and yield is more prominent, which indicate there are other influencing factors than these variables, such as climate and technology, influence these numbers. The skewness values for production, yield, and area under irrigation are 0.33, 0.53, and 0.26, respectively, indicating the data are mildly positively skewed and have a tendency to have values above the mean value. For all three, production with 1.99, yield at 2.55, and area under irrigation with 2.05, the kurtosis values are just barely above 2, which is positive for all of them. The correlation analysis shows a strong positive relationship between production and yield (correlation coefficient = 0.98), as well as between yield and area under irrigation (correlation coefficient = 0.76). This high correlation suggests that increases in yield and irrigation area are closely tied to higher rice production, making these variables essential for forecasting. The model stratifies the data on the basis of two yield thresholds: one yields less than or equal to 2391 kg/hectare and the other where it exceeded above this level. The model computes different regression equations for each regime, which then allows having unique intercept for the relevant coefficients of each variable within these regimes. This segmentation makes the TAR model very effective for agricultural application, as it adapts to changes in productivity caused by such factors as variations in climate or resource constraints.

Regression Equation for Yield \leq 2391 (61 Observations)

If the yield is up to 2391 kg/hectare, the regression equation is as follows:

$$\text{Production} = -23.56163 + (0.043978 \times \text{Yield}) + (0.419996 \times \text{Area under irrigation})$$

The intercept of -23.56163, theoretically means that, at zero yield and irrigation, production would be negative. This is of course, only hypothetical. The yield coefficient is 0.043978, indicating that every 1 kg/hectare increase in yield increases production by 0.044 million tonnes while an additional million hectares under irrigation expands production by 0.42 million tonnes. Both predictors are statistically significant at the 0.01 level ($p < 0.01$), indicating a strong influence on production

Regression Equation for Yield $>$ 2391 (10 Observations)

In this regime where the yield is more than 2391 kg/hectare the regression equation is as follows:

$$\text{Production} = -84.25757 + (0.003411 \times \text{Yield}) + (4.167946 \times \text{Area under irrigation})$$

The intercept of -84.25757 suggests that, at higher yield levels, the dynamics of production shift. The yield coefficient being 0.003411 implies an insignificant impact wherein an increase in yield by 1 kg/hectare results in an addition of only 0.0034 million tonnes to production. However, the irrigation coefficient at 4.167946 exemplifies a significant impact wherein each million hectares irrigated increases production by 4.17 million tonnes and, thus, establishes an indispensable role of irrigation during high-yield conditions. And while the yield coefficient is not statistically significant ($p = 0.2056$), irrigation remains highly significant ($p < 0.01$).

Residuals Plot

A residual plot of the Threshold Auto Regression (TAR) model would now become an important diagnostic tool since it helps to discover observed and predicted values of rice production as being different from each other (Setiya *et al.*, 2024). Ideally, residuals should be randomly scattered around zero with no visible patterns that indicate the underlying data structures are appropriately captured by the models. The residuals in this analysis seem to be evenly spread around the zero line with no peculiar trends, which is evidence that TAR has effectively decomposed the non-linear and threshold effects of yield and irrigation area on rice production, leaving only random error (Kastens *et al.*, 2005). This randomness offers scope for the assumptions of homoscedasticity—that is, constant variance—and independence with no autocorrelation—in the residuals (Paudel *et al.*, 2021). These two are crucial requirements for a model to have validity. The fact that there is no systematic pattern or clustering in the residuals also supports the idea that the TAR model captures all the significant relationships between variables, resulting in no major predictive bias. If patterns in the residual plot take the form of a funnel shape or wave-like formation, then funnel or wave-like shapes would depict some forms of heteroscedasticity or autocorrelation pointing to model inadequacy. But this perfectly regular, patternless residual distribution around zero in this case reinforces that the TAR model is well



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suited to capture the nuances of the rice production, including these thresholds, and thus validate its use as a reliable tool to forecast within this agricultural context. RMSE of 2.41 reflects the average value of error the model makes in predicting rice production values. Lower is the RMSE, the better fit is. This is a very good metric because greater errors incur more and one realizes how close the predictions are to the actual value on average. The MAE, at 1.62, brings a less complicated measure of mean prediction error without the magnification of large deviations whereby there is averaging of absolute differences between predicted and actual values of production. MAPE stands at 2.67%, meaning that this model predicts the values of production, on average, with almost an error of about 2.67% from the actual value, which is a minor error and goes to signify the high predictive accuracy. Further support to the strength of the model is provided by the level of 2.65% in sMAPE, thus giving a balanced measure of accuracy that reduces bias from the outliers. The Theil Inequality Coefficient was at 0.0166, which came close to the value of zero, thus pointing to almost perfect levels of forecasting accuracy. Taken together, these metrics confirm that the TAR model correctly extracts the main patterns from rice production data, producing reliable predictions that can actually be relied upon to provide planning and decision-making confidence in agriculture. The low error values found across all these metrics therefore emphasize the accuracy of the model and consolidate its utility in forecasting rice production under differing conditions of yield and irrigation.

Normality test

The histogram displays a right-skewed distribution of residuals, suggesting a tendency for the model to over predict rather than under predict. The mean (-1.92e-14) and median (0.42) are close to zero, indicating the model's overall accuracy. However, the standard deviation (2.43) and kurtosis (11.34) reveal significant variability and heavy tails in the residuals. The Jarque-Bera test statistic (267.64) with a p-value of 0.000000 confirms non-normality, violating a key assumption of many models. To improve the model, consider transformations, alternative models, outlier analysis, and further diagnostic checks. From the plot in the graph provided, no statistically significant process changes during the time span of 2016-2022 is shown, since the plot lies within the 5% significance limits. However, a gradual upward trend from the CUSUM plot might indicate an increasing variability of the process or a slight shift in the mean. For better understanding, probable causes like natural variation, minor changes in the processes, and issues associated with data quality may be analyzed. Monitor the process further, tighten the control limits as needed, and take corrective actions if any specific causes are identified

CONCLUSION

The fitted TAR model captured the non-linear dynamics and threshold effects involved among rice production, yield, and area under irrigation; that is, it had a very high R-squared value of 0.9937, that explained more than 99% of the variation in production. The developed statistics of performance, with a RMSE of 2.41, MAE of 1.62, and MAPE of 2.67%, establish the reliability of the model and its ability to predict the outcome of the crop. This study emphasizes the crucial function that irrigation plays in stabilizing production at higher yield levels besides highlighting thresholds where the effect of yield reveals signs of a downward trend. In this context, the TAR model turns out to be one of the best alternate forecasting models that capture all the non-linear relationships and threshold effects. This makes it highly suited for complex agricultural predictions

FUTURE SCOPE OF RESEARCH

Future research should extend this work by taking climatic conditions, technological advancement, and market dynamics into the model to enhance predictive power. Some of the more advanced models that one could use for testing, such as machine learning algorithms like Random Forest or Neural Networks, may improve the model's accuracy and flexibility further. Regional analysis could also make provision for regional-level insights into the dynamics of production, so targeted interventions can be taken in these regions. Residual non-normality can also be addressed or even hybrid modelling techniques might open doors to further improvement of the framework for wider application in agricultural forecasting.



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Table 1: Descriptive statistics

Observation	Production (Million Tonnes)	Yield (Kg. /Hectare)	Area under irrigation (Million Hectares)
Mean	65.84644	1605.589	43.91096
Median	60.56000	1471.000	43.60000
Maximum	134.0000	3494.000	58.70000
Minimum	20.58000	668.0000	31.70000
Standard Deviation	30.69231	635.5626	7.051331
Skewness	0.329292	0.533986	0.261349
Kurtosis	1.990631	2.550270	2.053302
Jarque-Bera	4.418202	4.084415	3.557073
Probability	0.109799	0.129742	0.168885
Sum	4806.790	117208.0	3205.500
Observations	67825.27	29083668	3579.931

Table 2: Correlation Values across the variables

Observation	Production	Yield	Area under irrigation
Production	1		
Yield	0.98017286	1	
Area under irrigation	0.79673770	0.75770492	1

Table 3: Observations of variable using Threshold Auto Regression

Variable	Coefficient	Std. Error	t- Statistic	Prob
Regime 1: Yield <= 2391 – 61 Observations				
C	-23.56163	3.634592	-6.482607	0.0000
Yield	0.043978	0.002404	18.29468	0.0000
Area under irrigation	0.419996	0.156325	20686691	0.0091
Regime 2: 2392 <= Yield – 10 Observations				
C	-84.25757	18.16360	-4.638814	0.0000
Yield	0.003411	0.002669	1.278294	0.2056
Area under irrigation	4.167946	0.395639	10.53471	0.0000
R- Square	0.993730			
Adj R – Square	0.993262			
SE Of Regression	2.519395			
SSR	425.2725			
F – Statistic	2123.721			
Prob (F- statistic)	0.000000			
AIC	4.764531			
Schwartz Criterion	4.952788			





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Hannan-criter	4.839555	
Durbin – Watson Stat	1.486523	
R- Square	0.993730	

Table 4: error metrics

RMSE	MAE	MAPE	Symmetric MAPE	Theil Inequality Coefficient
2.413638	1.621480	2.670938	2.647997	0.016637

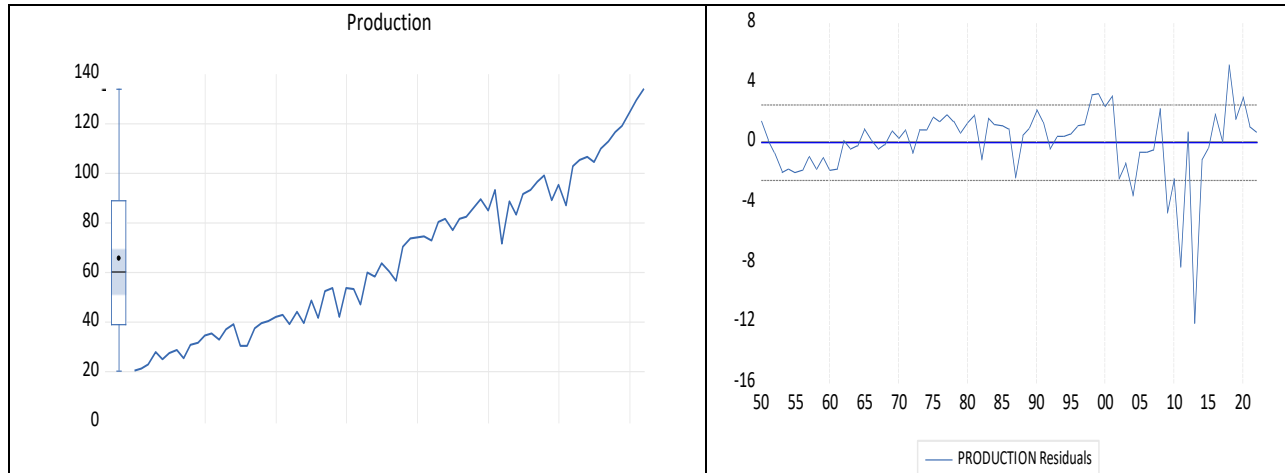


Fig 1: Rice production plot from 1950 to 2022

Fig 2: Residual plot of Rice production

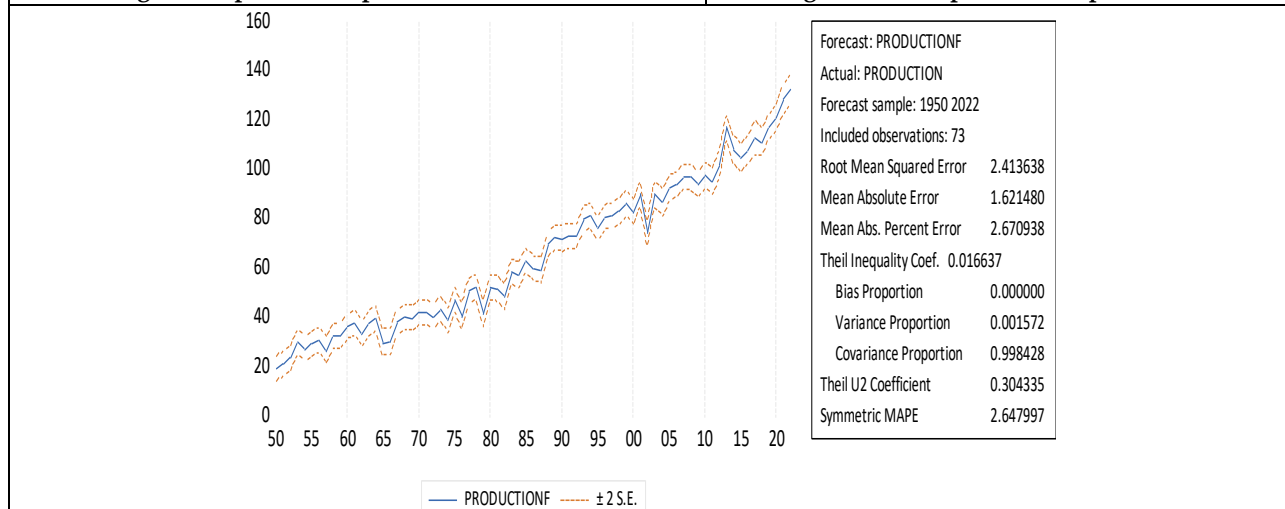


Fig 3: Production forecasting





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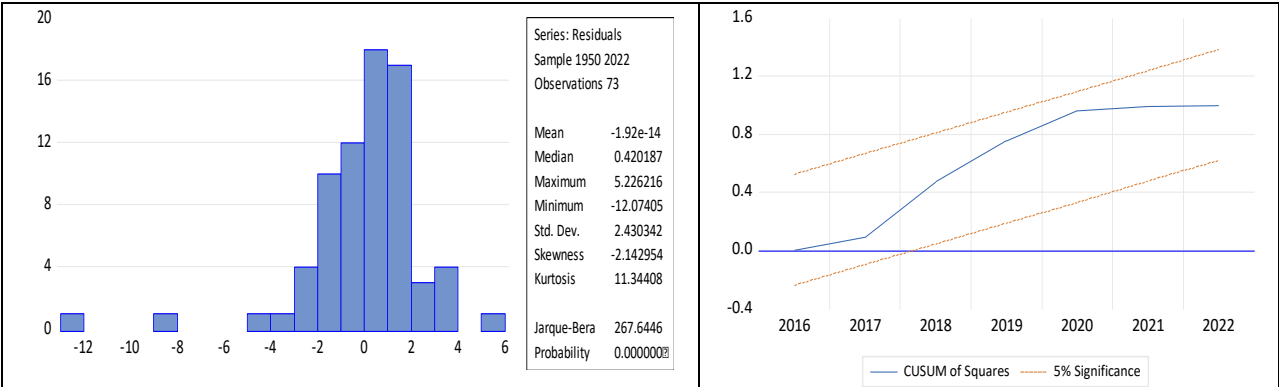


Fig 4: Histogram and CUSUM chart





Dynamics of an Influenza Epidemic Model with Vaccination and Treatment

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ABSTRACT

This study presents a non-linear epidemic mathematical model that takes into account the impact of vaccination and treatment on the spread of Influenza. The model was thoroughly analyzed to gain insights into the dynamics of the disease. The paper explores the stability of the disease-free equilibrium, both at a local and global level. Additionally, the model calculates the basic reproduction number, R_0 . The model is applied to the influenza cases in India from 2010 to 2023. We are currently utilizing the normalized forward sensitivity index method to analyze the sensitivity of the parameters in relation to R_0 . An analysis is conducted on the influence of vaccination and treatment rates on populations that have been infected. The optimal control approach focuses on continuously vaccinating individuals who are still susceptible and aims to enhance the treatment for those who are infected. The combination of treatment and vaccine strategies has shown promising results, leading to a significant decrease in the prevalence of disease within the desired timeframe.

Keywords: Local stability, Global stability, Endemic equilibrium, Disease free equilibrium, Sensitive analysis, Optimal control.

AMS Subject classification: 34G20, 49M05, 93D20





INTRODUCTION

Mathematical modeling is a crucial method for understanding the spread and management of many infectious illnesses. Mathematical models consider various crucial factors such as vaccination, transmission, recovery, and other elements that influence the progression of a disease [2],[3],[4] and [5]. Optimal control theory, a branch of mathematics, was developed to ascertain the most effective approach for regulating dynamic systems. The aim of utilizing optimum control theory is to compute the efficacy of various policies and control systems, along with their associated expenses [6],[7] and [8]. Vaccination is a widely employed method of disease control. Based on calculations, implementing a vaccination program would prevent approximately 2-3 million deaths each year. Recently, vaccination and other preventative techniques such as treatment, isolation, screening, and quarantine have been employed to diminish the transmission of infectious diseases [9]. Srivastav et.al. [10] examined epidemic models that include vaccination and the latent stage. Srivastav et.al. [11] constructed an optimal control model that integrates the disease transmission rate and treatment rate. Asymptomatic individuals who are affected with the disease remain contagious and facilitate the transmission of the disease from one person to another [12]. A decrease in immune function might heighten an individual's vulnerability to a range of diseases resulting from asymptomatic infections. Prior to undergoing medical testing, the absence of symptoms in the patient may remain undetected. Consequently, certain individuals may endure extended durations without manifesting any symptoms, perhaps leading to their demise [13]. Multiple studies indicate that approximately one-third of infections are asymptomatic infections [14] and [15]. Stilianakis et al. [16] developed a model that incorporates the asymptomatic compartment into a SARS epidemic model. This model was used to assess the impact of treatment and chemotherapy regimens on the transmission of the disease. The influenza virus primarily targets the nasal passages, throat, bronchial tubes, and, in rare cases, the lungs. The symptoms of infection, which have a normal duration of one week, encompass fever, myalgia, headache, pharyngitis, coughing, and prostration. Influenza is highly contagious and easily transmitted by direct exposure to respiratory droplets expelled by an infected individual through coughing and sneezing. The ailment impacts the respiratory system, specifically the lungs, throat, or nose. It often originates as an epidemic that rapidly disseminates from urban areas to rural areas and from one region to another. The duration of an outbreak in a certain region normally spans 4-6 weeks before it diminishes. Owing to its high transmissibility, influenza has the potential to rapidly induce a widespread outbreak of sickness among a substantial population. The swine flu pandemic emerged in 2009, originating in Mexico and rapidly spreading to other parts of the world due to its highly contagious nature and the swift transportation of infected individuals across nations via air travel. This virus seems to be a hybrid of four distinct strains. There are four endemic strains of the influenza A virus: variation H1N1, which primarily infects people, a strain that infects birds, and two strains that infect pigs (swine). The World Health Organization [1] declared the flu as a pandemic on August 10, 2010. A novel SVL I_aI_s TRD epidemiological model has been constructed by integrating three distinct categories, namely asymptomatic, treatment, and deceased, into the existing SVEIR model [10] for the transmission of the influenza virus. The basic reproductive number is computed, followed by an assessment of the stability of the disease-free equilibrium. The model is calibrated using data from India and a sensitivity analysis is conducted. In addition, we expanded our model to incorporate an optimal control model problem with two control functions: vaccination and treatment controls, in order to reduce both the number of infected individuals and the number of fatalities.

MODEL FORMATION

This work presents the development of the SVL I_aI_s TRD epidemiological model, which incorporates vaccination and therapy, to illustrate the transmission dynamics of Influenza in India. The population $N(t)$ at time t is partitioned into 8 distinct compartments, referred to as susceptible ($S(t)$), vaccinated ($V(t)$), exposed ($L(t)$), asymptomatic infected ($I_a(t)$), symptomatic infected ($I_s(t)$), recovered ($R(t)$), and deceased ($D(t)$). Therefore $N(t) = S(t) + V(t) + L(t) + I_a(t) + I_s(t) + T(t) + R(t) + D(t)$. It is assumed that all individuals have an equal probability of becoming infected if they come into contact with diseased persons. This assumption is based on the belief that the overall population is both homogeneous and uniformly dispersed. The population of individuals who are infected can be categorized into two distinct groups: symptomatic infected individuals ($I(t)$), who exhibit symptoms of the disease,





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and asymptomatic infected individuals ($A(t)$), who do not display any symptoms of the disease. The infectivity of $A(t)$ seems to be lower than that of $I(t)$.

The susceptible population ($S(t)$) refers to those who are currently susceptible to illness but do not currently have an infection. The population is determined by the rate of recruitment or birth (Π) and is reduced by the natural mortality rate (δ). An individual who is vulnerable to the virus and comes into touch with an infected individual at a rate β will become part of the exposed population. The decline occurs due to a low vaccination rate η , resulting in only a small number of susceptible individuals receiving immunizations. Thus

$$\frac{dS}{dt} = \Pi - \beta S(\zeta I_a + \phi I_s) - (\eta + \delta)S$$

The vaccinated population ($V(t)$) refers to the subset of the vulnerable population who have received vaccination. The population undergoes growth at a pace determined by the vaccination rate η and experiences decline due to the natural death rate δ . This population may see a resurgence of the disease because of the vaccine's inefficacy, leading to a drop in population at a rate of ψ . So

$$\frac{dV}{dt} = \eta S - \beta \phi V(\zeta I_a + \phi I_s) - (\gamma_v + \delta)V$$

The exposed population ($L(t)$) refers to individuals who have been exposed to the virus but have not yet become infectious. Once the individuals who have been exposed to the virus become sick, a fraction (α) of those who do not show any symptoms associated to the virus migrate to group A at a rate of σ , while the remaining fraction ($1 - \alpha$) of individuals who do exhibit virus-related symptoms move to group I. The population undergoes a decline at a rate of σ . The population grows as susceptible individuals become exposed to the virus and vaccinated persons become infected due to the ineffectiveness of the vaccination. This population decreases due to the natural mortality rate δ . Therefore

$$\frac{dL}{dt} = \beta S(\zeta I_s + \zeta I_a) + \beta \phi V(\zeta I_a + \phi I_s) - (\sigma + \delta)L$$

The asymptomatic population ($I_a(t)$) is considered to be infected while not displaying symptoms. The production of these people occurs at a rate of $\alpha\sigma$ relative to the exposed population and diminishes at a rate of δ . As a result of some individuals in this group naturally recovering without treatment due to their immune system, while others develop disease symptoms and migrate to I_s , the population shrinks at rates θ and γ_a . So that

$$\frac{dI_a}{dt} = \alpha\sigma L - (\theta + \gamma_a + \delta)I_a$$

The symptomatic population ($I_s(t)$) refers to those who have been infected and are displaying signs of the disease. The individuals are produced at a rate of $(1 - \alpha)\sigma$ from the exposed population and decrease at a rate of δ . As a result of a serious disease, a portion of these folks succumbed while others were admitted to the hospital for improved medical care. Therefore, this population decreases at the rates κ and δ_s . Thus

$$\frac{dI_s}{dt} = (1 - \alpha)\sigma L + \theta I_s - (\kappa + \delta_s + \delta)I_s$$

The Treatment population ($T(t)$) refers to those who are hospitalized as a result of their sickness. The population increases at a rate of κ and decreases at a rate of δ . Due to variations in treatment effectiveness and the severity of sickness, the population experiences declines at rates γ_t and δ_t , resulting in some persons recovering and others succumbing to their illness. Hence

$$\frac{dT}{dt} = \kappa I_s - (\gamma_t + \delta_t + \delta)T$$

The Recovered population ($R(t)$) refers to those who have successfully overcome a sickness. The population grows at rates γ_a and γ_t , and decreases at a rate δ . Hence





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$$\frac{dR}{dt} = \gamma_a I_a + \gamma_t T - \delta R$$

The Deceased population ($D(t)$) refers to those who have succumbed to a serious infection. This population increases at the rates δ_a and δ_t . Thus

$$\frac{dD}{dt} = \delta_s I_s + \delta_t T$$

The proposed model is given by following system of non – linear differential equations

$$\frac{dS}{dt} = \Pi - \beta S(\zeta I_a + \varrho I_s) - (\eta + \delta)S$$

$$\frac{dV}{dt} = \eta S - \beta \phi V(\zeta I_a + \varrho I_s) - (\gamma_v + \delta)V$$

$$\frac{dL}{dt} = \beta S(\zeta I_a + \varrho I_s) + \beta \phi V(\zeta I_a + \varrho I_s) - (\sigma + \delta)L$$

$$\frac{dI_a}{dt} = \alpha \sigma L - (\theta + \gamma_a + \delta)I_a \quad 1$$

$$\frac{dI_s}{dt} = (1 - \alpha)\sigma L + \theta I_a - (\kappa + \delta_s + \delta)I_s$$

$$\frac{dT}{dt} = \kappa I_s - (\gamma_t + \delta_t + \delta)T$$

$$\frac{dR}{dt} = \gamma_v V + \gamma_a I_a + \gamma_t T - \delta R$$

$$\frac{dD}{dt} = \delta_s I_s + \delta_t T$$

with the primary conditions $S(0) \geq 0, V(0) \geq 0, L(0) \geq 0, I_a(0) \geq 0, I_s(0) \geq 0, T(0) \geq 0, R(0) \geq 0$, and $D(0) \geq 0$. The model is graphically represented in Fig.1 and the model parameters is described in Table 1

SVLI_aI_sTRD MODEL ANALYSIS

Positivity and boundedness

Theorem 1 The solutions $(S, V, L, I_a, I_s, T, R, D)$ of the system (1) are non-negative for any $t > 0$, assuming non-negative fundamental conditions. Moreover $\lim_{t \rightarrow \infty} \sup N \leq \frac{\Lambda}{\mu}$

Proof. Let $T = \sup \{t > 0 : (S, V, L, I_a, I_s, T, R, D > 0)\}$. Then $T > 0$. From the first equation of system (1), we get

$$\frac{dS}{dt} = \Pi - \beta S(\zeta I_a + \varrho I_s) - (\eta + \delta)S \geq \Pi - \chi(t)S$$

where $\chi(t) = \beta(\zeta I_a + \varrho I_s) + (\eta + \delta)$

Then $\frac{dS}{dt} + \chi(t)S \geq \Pi$

$$\frac{d}{dt} \left[S(t) \exp \left(\int_0^t \chi(u) du \right) \right] = \Pi \left[\exp \left(\int_0^t \chi(u) du \right) \right]$$

$$\Rightarrow S(t) \exp \left(\int_0^t \chi(u) du \right) = S(0) + \int_0^t \Lambda \exp \left(\int_0^y \chi(v) dv \right) dy$$





So that

$$S(T) = S(0) \exp \left(- \int_0^T \chi(u) du \right) + \int_0^T \Lambda \exp \left(\int_0^y \chi(v) dv \right) dy \times \exp \left(- \int_0^T \chi(u) du \right) > 0$$

$$\Rightarrow S(T) > 0$$

Similarly we can prove that $V(t) > 0, L(t) > 0, I_a(t) > 0, I_s(t) > 0, T(t) > 0, R(t) > 0$ and $D(t) > 0 \forall t > 0$

As a result, for any $t > 0$, all model solutions with non-negative primary conditions remain non negative.

Theorem 2. For the system (1) with primary conditions in \mathbf{R}_+^8 , the region Ω is positively invariant

Proof.

By adding all the equations of system (1), we get

$$\frac{dN}{dt} = \Pi - \delta N$$

Which leads to $\lim_{t \rightarrow \infty} \sup N \leq \frac{\Pi}{\delta}$

Then we get $N \leq \frac{\Pi}{\delta}$

Therefore $N(t) \rightarrow \frac{\Pi}{\delta}$ as $t \rightarrow \infty$

If $N > \frac{\Pi}{\delta}$, then $\frac{dN}{dt} < 0$

From the first and second equations of (1), we get

$$\lim_{t \rightarrow \infty} \sup S \leq \frac{\Pi}{(\eta + \delta)} \text{ and } \lim_{t \rightarrow \infty} \sup V \leq \frac{\Pi \eta}{\delta(\eta + \delta)}$$

Therefore, the region of attraction for the system (1) is given by

$$\Omega = \left\{ (S, V, L, I_a, I_s, T, R, D) \in \mathbf{R}_+^8 : 0 \leq \left(S + V + L + I_s + I_a + T + R + D \leq \frac{\Pi}{\delta}, S \leq \frac{\Pi}{(\eta + \delta)}, V \leq \frac{\Pi \eta}{(\gamma_v + \delta)(\eta + \delta)} \right) \right\}$$

The given set is considered a positive invariant set as it encompasses all solutions of system (1) with initial conditions within Ω for every time $t > 0$.

Basic reproduction number

The illness free equilibrium corresponds to the point E_0 at which infection disappears (i.e., $L = I_a = I_s = T = 0$) from the population is $E_0 = \left(\frac{\Pi}{(\eta + \delta)}, \frac{\Pi \eta}{(\gamma_v + \delta)(\eta + \delta)}, 0, 0, 0, 0, 0 \right)$.

Here, using the Next-generation technique described in [23] and [24], we derive the corresponding basic reproduction number for the system (1).

Let $y = (L, I_a, I_s, T)^T$. Then the system (1) can be written as $\frac{dy}{dt} = F(y) - V(y)$

where

$$F(y) = \begin{bmatrix} \beta S(\zeta I_a + \varrho I_s) + \beta \phi V(\zeta I_a + \varrho I_s) \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \text{ and } V(y) = \begin{bmatrix} (\sigma + \delta)L \\ -\alpha \sigma L + (\theta + \gamma_a + \delta)I_a \\ -(1 - \alpha)\sigma L - \theta I_a + (\kappa + \delta_s + \delta)I_s \\ -\kappa I_s + (\gamma_t + \delta_t + \delta)T \end{bmatrix}$$

$$\text{We can get } F = \begin{pmatrix} 0 & \frac{\beta \Pi \zeta (\delta + \eta \phi)}{(\gamma_v + \delta)(\eta + \delta)} & \frac{\beta \Pi \varrho (\delta + \eta \phi)}{(\gamma_v + \delta)(\eta + \delta)} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \text{ and } V = \begin{pmatrix} (\sigma + \delta) & 0 & 0 \\ -\alpha \sigma & (\theta + \gamma_a + \delta) & 0 \\ -(1 - \alpha)\sigma & -\theta & (\kappa + \delta_s + \delta) \end{pmatrix}$$

$$\text{Then } V^{-1} = \begin{pmatrix} \frac{1}{(\sigma + \delta)} & 0 & 0 \\ \frac{\alpha \sigma}{(\sigma + \delta)(\theta + \gamma_a + \delta)} & \frac{1}{(\theta + \gamma_a + \delta)} & 0 \\ \frac{\alpha \sigma (\sigma + \delta) + (1 - \alpha)\sigma(\theta + \gamma_a + \delta)}{(\sigma + \delta)(\theta + \gamma_a + \delta)(\kappa + \delta_s + \delta)} & \frac{\theta}{(\theta + \gamma_a + \delta)(\kappa + \delta_s + \delta)} & \frac{1}{(\kappa + \delta_s + \delta)} \end{pmatrix}$$





Since the largest eigen value of the matrix FV^{-1} is the reproduction number (R_0), the basic reproduction number is

$$R_0 = \frac{(\delta + \eta\phi)\beta\Pi [\zeta\alpha\sigma(\kappa + \delta_s + \delta) + \varrho(\alpha\sigma\theta + (1 - \alpha)\sigma(\theta + \gamma_a + \delta))]}{(\eta + \delta)(\gamma_v + \delta)(\theta + \gamma_a + \delta)(\kappa + \delta_s + \delta)(\sigma + \delta)}$$

Local and global stability of disease free equilibrium

Theorem 3: The disease free equilibrium $E_0 = \left(\frac{\Pi}{(\eta + \delta)}, \frac{\Pi\eta}{(\gamma_v + \delta)(\eta + \delta)}, 0, 0, 0, 0\right)$ of the system (1) exhibited local asymptotic stability when the value of $R_0 < 1$.

Proof

The Jacobian matrix corresponding to the system (1) at disease free equilibrium point E_0 is

$$J(E_0) = \begin{pmatrix} -(\eta + \delta) & 0 & 0 & -\beta\zeta & -\beta\varrho & 0 & 0 \\ 0 & -(\gamma_v + \delta) & 0 & \beta\phi\zeta & \beta\phi\varrho & 0 & 0 \\ 0 & 0 & -(\sigma + \delta) & \beta\zeta(1 + \phi) & \beta\varrho(1 + \phi) & 0 & 0 \\ 0 & 0 & \alpha\sigma & -(\theta + \gamma_a + \delta) & 0 & 0 & 0 \\ 0 & 0 & (1 - \alpha)\sigma & \theta & -(\kappa + \delta_s + \delta) & 0 & 0 \\ 0 & 0 & 0 & \gamma_a & \kappa & -(\gamma_t + \delta_t + \delta) & 0 \\ 0 & 0 & 0 & 0 & 0 & \gamma_t & -\delta \end{pmatrix}$$

The characteristic equation is

$$(\lambda + (\eta + \delta))(\lambda + (\gamma_v + \delta))(\lambda + \delta)(\lambda + (\gamma_t + \delta_t + \delta)) \begin{vmatrix} -(\sigma + \delta) & \beta\zeta(1 + \phi) & \beta\varrho(1 + \phi) \\ \alpha\sigma & -(\theta + \gamma_a + \delta) & 0 \\ (1 - \alpha)\sigma & \theta & -(\kappa + \delta_s + \delta) \end{vmatrix} = 0$$

Here $-\delta$, $-(\eta + \delta)$, $-(\gamma_v + \delta)$ and $-(\gamma_t + \delta_t + \delta)$ are the four eigen values of $J(E_0)$ and the remaining three eigen values are obtained from the cubic equation $(\lambda^3 + a_1\lambda^2 + a_2\lambda + a_3) = 0$

Where $a_1 = (\sigma + \delta) + (\theta + \gamma_a + \delta) + (\kappa + \delta_s + \delta)$

$$a_2 = (\sigma + \delta)(\theta + \gamma_a + \delta) + ((\sigma + \delta) + (\theta + \gamma_a + \delta))(\kappa + \delta_s + \delta) - \beta(1 + \phi)(\zeta\alpha\sigma + \varrho(1 - \alpha)\sigma)a_3 = \frac{(\sigma + \delta)(\theta + \gamma_a + \delta)(\kappa + \delta_s + \delta)}{(\delta + \eta\phi)\Pi} [(\delta + \eta\phi)\Pi - (1 + \phi)(\eta + \delta)(\gamma_v + \delta) + (1 + \phi)(\eta + \delta)(\gamma_v + \delta)(1 - R_0)]$$

Using Liénard-Chipart test the disease free equilibrium point E_0 is locally asymptotically stable if $a_1, a_2, a_3 > 0$ and $a_1a_2 > a_3$

Clearly $a_1 > 0$, $a_2 > 0$ and $a_3 > 0$ if $R_0 < 1$

It is easily to verify that $a_1a_2 > a_3$ for $R_0 < 1$

Hence the disease free equilibrium point E_0 was locally asymptotically stable if $R_0 < 1$.

Theorem4: The disease free equilibrium $E_0 = \left(\frac{\Pi}{(\eta + \delta)}, \frac{\Pi\eta}{(\gamma_v + \delta)(\eta + \delta)}, 0\right)$ of system (1) exhibited global asymptotic stability when the value of $R_0 < 1$.

Proof .

The system (1) can be written in this form:

$$\frac{dX}{dt} = P(X, Y), \frac{dY}{dt} = Q(X, Y) \text{ and } G(X, 0) = 0 \quad (*)$$

where $X = (S, V, R) \in \mathbb{R}_+^3$, $Y = (E, I_a, I_s, T) \in \mathbb{R}_+^4$ representing the number of uninfected and infected populations respectively. Then the disease free equilibrium is denoted by $E_0 = \left(\frac{\Pi}{(\eta + \delta)}, \frac{\Pi\eta}{(\gamma_v + \delta)(\eta + \delta)}, 0\right)$

For E_0 is global asymptotically stable, the following two conditions (H_1) and (H_2) must be satisfied.

(H_1): $\frac{dX}{dt} = P(X_0, 0)$, X_0 is globally asymptotic stable.

(H_2): $Q(X, Y) = BY - \widehat{Q}(X, Y)$, $\widehat{Q}(X, Y) \geq 0$, here $B = D_Y Q(X_0, 0)$ is M matrix.





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The system (1) can be rewritten as $P(X, 0) = \begin{pmatrix} \Pi - (\eta + \delta)S \\ \eta S - (\gamma_v + \delta)V \\ -\delta R \end{pmatrix}$
 $S(t) = \frac{\Pi}{(\eta + \delta)} - \frac{s(0)}{(\eta + \delta)} e^{-(\eta + \delta)t}$ and $V(t) = \frac{\Pi\eta}{(\gamma_v + \delta)(\eta + \delta)} - \frac{v(0)}{(\gamma_v + \delta)(\eta + \delta)} e^{-(\eta + \delta)t}$ and $R(t) = e^{-\delta t}$
 As $t \rightarrow \infty$, $X_0 = \left(\frac{\Pi}{(\eta + \delta)}, \frac{\Pi\eta}{(\gamma_v + \delta)(\eta + \delta)}, 0 \right)$ is global asymptotically stable for $\frac{dX}{dt} = P(X_0, 0)$.

Hence the first condition (H_1) is verified.

Band $\hat{Q}(X, Y)$ expressed as

$$B = \begin{pmatrix} -(\sigma + \delta) & \beta\zeta(1 + \phi) & \beta\varrho(1 + \phi) & 0 \\ \alpha\sigma & -(\theta + \gamma_a + \delta) & 0 & 0 \\ (1 - \alpha)\sigma & \theta & -(\kappa + \delta_s + \delta) & 0 \\ 0 & \gamma_a & \kappa & -(\gamma_t + \delta_t + \delta) \end{pmatrix} \text{ and } \hat{Q}(X, Y) = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Hence B is an M matrix. Thus the two conditions are verified.

Therefore disease-free equilibrium E_0 of system (1) was globally asymptotic stable if $R_0 < 1$.

Numerical Simulation

Model fitting

The suggested model was applied to the cumulative confirmed instances of influenza and cumulative influenza-related mortality in India [25] throughout the time span from 2010 to 2023. The parameters β and θ are computed by minimizing the sum of squared error technique using the lsqnonlin function in MATLAB. The given data is represented by blue circles in Fig.2, whereas the model solution is represented by a red circle.

Sensitivity Analysis

The sensitivity analysis played a vital role in determining the impact of various parameters on the transmission of influenza. This technique is particularly valuable for detecting variations in the R_0 value in relation to other factors. We do sensitivity analysis to evaluate the influence of factors on the model. The normalized forward sensitivity index for the significant parameter p in R_0 was determined using the normalized forward sensitivity method [25] as $\Gamma_p^{R_0} = \frac{\partial R_0}{\partial p} \frac{p}{R_0}$.

Fig. 3 presented the sensitivity indices of R_0 in relation to different parameters. Indices with greater magnitude exhibit more sensitivity to variations in R_0 . When the sensitivity index is positive, the value of R_0 grows as the value of p increases. Similarly, when the sensitivity index is negative, a rise in p leads to a drop in R_0 . Our sensitivity analysis indicates that the parameters $\Pi, \zeta, \varrho, \sigma, \phi, \theta$ and β positively affect R_0 , while the parameters $\eta, \kappa, \gamma_v, \gamma_a, \delta_s$ and δ negatively affect R_0 . The parameters ϱ, β , and ϕ have a greater impact on the transmission of influenza, while the parameters η, κ, γ_v and γ_a are more successful in reducing the influenza. The vaccination rate and treatment rate are utilized to assess the prevalence of the influenza-infected population. Based on the observations from Fig. 4a and Fig. 4b, it can be inferred that an increase in the vaccination rate (η) and treatment rate (κ) leads to a decrease in the spread of influenza.

Optimal control

Optimal control for the $SVLI_a I_s TRD$ model

The system (1) is expanded in this part to include optimal control issue by integrating two distinct control factors, u_1 and u_2 . Vaccines are administered to this specific group of individuals with the purpose of enhancing their immune system's ability to recognize the disease and eliminate any related microorganisms they may encounter in the future. u_1 refers to vaccine control, which mandates that all individuals who are vulnerable to influenza must receive a vaccination in order to minimize the continued transmission of the virus. In order to mitigate the severity of diseases and halt the transmission of infections, enhanced medical care is provided to specific subsets of the affected





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population. The variable u_2 indicates the control group for patients infected with influenza who are receiving treatment. Considering all above assumptions, the optimal control model is formulated as follows:

$$\frac{dS}{dt} = \Pi - \beta S(\zeta I_a + \varrho I_s) - (u_1 + \delta)S$$

$$\frac{dV}{dt} = u_1 S - \beta \phi V(\zeta I_a + \varrho I_s) - (\gamma_v + \delta)V$$

$$\frac{dL}{dt} = \beta S(\zeta I_a + \varrho I_s) + \beta \phi V(\zeta I_a + \varrho I_s) - (\sigma + \delta)L$$

$$\frac{dI_a}{dt} = \alpha \sigma L - (\theta + \gamma_a + \delta)I_a \quad (2)$$

$$\frac{dI_s}{dt} = (1 - \alpha)\sigma L + \theta I_a - (\kappa + u_2 + \delta_s + \delta)I_s$$

$$\frac{dT}{dt} = (\kappa + u_2)I_s - (\gamma_t + \delta_t + \delta)T$$

$$\frac{dR}{dt} = \gamma_v V + \gamma_a I_a + \gamma_t T - \delta R$$

$$\frac{dD}{dt} = \delta_s I_s + \delta_t T$$

Where objective functional for fixed time t_f is

$$J = \int_0^{t_f} (C_1 I_a + C_2 I_s + C_3 T) + \left(\left(\frac{C_4}{2} \right) u_1^2 + \left(\frac{C_5}{2} \right) u_2^2 \right) dt \quad (3)$$

Where C_1, C_2, C_3, C_4 and C_5 are nonnegative weight constants.

Our main objective is to find the control variables u_1^* and u_2^* such that

$$J(u_1^*, u_2^*) = \min_{u_1, u_2 \in U} J(u_1, u_2) \quad (4)$$

where $U = \{u_1, u_2 : \text{measurable and } 0 \leq u_1, u_2 \leq 1\}$ and $t \in [0, t_f]$.

The Hamiltonian function (H) are defined as

$$H = (C_1 I_a + C_2 I_s + C_3 T) + \left(\left(\frac{C_4}{2} \right) u_1^2 + \left(\frac{C_5}{2} \right) u_2^2 \right) + \lambda_1 \frac{dS}{dt} + \lambda_2 \frac{dV}{dt} + \lambda_3 \frac{dL}{dt} + \lambda_4 \frac{dI_a}{dt} + \lambda_5 \frac{dI_s}{dt} + \lambda_6 \frac{dT}{dt} + \lambda_7 \frac{dR}{dt} + \lambda_8 \frac{dD}{dt}$$

where $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6, \lambda_7$ and λ_8 are the adjoint variables.

Theorem.5

If $(S^*, V^*, L^*, I_a^*, I_s^*, T^*, R^*, D^*)$ is the solution of the system (2) associated to the optimal controls u_1^*, u_2^* and $u_3^* \in U$, then there exist an adjoint functions $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6, \lambda_7$ and λ_8 satisfying the equation

$$\frac{d\lambda_1}{dt} = \frac{\partial H}{\partial S} = (\lambda_1 - \lambda_3) \beta (\zeta I_a + \varrho I_s) \frac{1}{N} + (\lambda_1 - \lambda_2) (u_1) + \lambda_1 \delta$$

$$\frac{d\lambda_2}{dt} = \frac{\partial H}{\partial V} = (\lambda_2 - \lambda_3) \beta \phi (\zeta I_a + \varrho I_s) \frac{1}{N} + (\lambda_2 - \lambda_7) \gamma_v + \lambda_2 \delta$$

$$\frac{d\lambda_3}{dt} = \frac{\partial H}{\partial L} = (\lambda_3 - \lambda_5) \sigma + (\lambda_5 - \lambda_4) \sigma \alpha + \lambda_3 \delta$$

$$\frac{d\lambda_4}{dt} = \frac{\partial H}{\partial I_a} = -C_1 + (\lambda_1 - \lambda_3) \beta \zeta \frac{S}{N} + (\lambda_2 - \lambda_3) \beta \phi \zeta \frac{V}{N} + (\lambda_4 - \lambda_7) \gamma_a + (\lambda_4 - \lambda_5) \theta + \lambda_4 \delta$$

$$\frac{d\lambda_5}{dt} = \frac{\partial H}{\partial I_s} = -C_2 + (\lambda_1 - \lambda_3) \beta \varrho \frac{S}{N} + (\lambda_2 - \lambda_3) \beta \phi \varrho \frac{V}{N} + (\lambda_5 - \lambda_6) (\kappa + u_2) + (\lambda_5 - \lambda_7) \delta_s + \lambda_5 \delta$$

$$\frac{d\lambda_6}{dt} = \frac{\partial H}{\partial T} = -C_3 + (\lambda_6 - \lambda_7) \gamma_t + (\lambda_6 - \lambda_8) \delta_t + \lambda_6 \delta$$

$$\frac{d\lambda_7}{dt} = \frac{\partial H}{\partial R} = \lambda_7 \delta$$

$$\frac{d\lambda_8}{dt} = \frac{\partial H}{\partial D} = 0$$

with the transversality conditions at time t_f ,





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$\lambda_S(t_f) = 0, \lambda_V(t_f) = 0, \lambda_{I_a}(t_f) = 0, \lambda_{I_s}(t_f) = 0, \lambda_T(t_f) = 0, \lambda_R(t_f) = 0$ and $\lambda_D(t_f) = 0$

Furthermore, for $t \in [0, t_f]$, the optimal controls u_1^*, u_2^* and u_3^* are determined by

$$u_1^* = \min \left\{ 1, \max \left(0, \frac{(\lambda_1 - \lambda_2)S}{C_4} \right) \right\} \text{ and } u_2^* = \min \left\{ 1, \max \left(0, \frac{(\lambda_5 - \lambda_6)I_s}{C_5} \right) \right\}$$

Proof

The Hamiltonian function for the optimal control system(2) is

$$\begin{aligned} H = & (C_1 I_a + C_2 I_s + C_3 T) + \left(\frac{C_4}{2} \right) u_1^2 + \left(\frac{C_5}{2} \right) u_2^2 + \lambda_1 (\Pi - \beta S (\zeta I_a + \rho I_s) - (u_1 + \delta) S) + \lambda_2 (u_1 S \\ & - \beta \phi V (\zeta I_a + \rho I_s) - (\gamma_v + \delta) V) + \lambda_3 (\beta S (\zeta I_a + \rho I_s) + \beta \phi V (\zeta I_a + \rho I_s) - (\sigma + \delta) L) + \lambda_4 (\alpha \sigma L \\ & - (\theta + \gamma_a + \delta) I_a) + \lambda_5 ((1 - \alpha) \sigma L + \theta I_a - (\kappa + \delta_s + u_2 + \delta) I_s) + \lambda_6 (\kappa I_s - (\gamma_t + \delta_t + \delta) T) \\ & + \lambda_7 (\gamma_v V + \gamma_a I_a + \gamma_t T - \delta R) + \lambda_8 (\delta_s I_s + \delta_t T) \end{aligned}$$

Through Pontryagin's maximal principle [27], there exists a co-state variable that satisfy the canonical expressions as follows,

$$\frac{d\lambda_1}{dt} = -\frac{\partial H}{\partial S}, \lambda_S(t_f) = 0$$

$$\frac{d\lambda_2}{dt} = -\frac{\partial H}{\partial V}, \lambda_V(t_f) = 0$$

$$\frac{d\lambda_3}{dt} = -\frac{\partial H}{\partial L}, \lambda_L(t_f) = 0$$

$$\frac{d\lambda_4}{dt} = -\frac{\partial H}{\partial I_a}, \lambda_{I_a}(t_f) = 0$$

$$\frac{d\lambda_5}{dt} = -\frac{\partial H}{\partial I_s}, \lambda_{I_s}(t_f) = 0$$

$$\frac{d\lambda_6}{dt} = -\frac{\partial H}{\partial T}, \lambda_T(t_f) = 0$$

$$\frac{d\lambda_7}{dt} = -\frac{\partial H}{\partial R}, \lambda_R(t_f) = 0$$

$$\frac{d\lambda_8}{dt} = -\frac{\partial H}{\partial D}, \lambda_D(t_f) = 0$$

Now using the optimal condition $\frac{\partial H}{\partial u_1} = 0, \frac{\partial H}{\partial u_2} = 0$ and $\frac{\partial H}{\partial u_3} = 0$, we get

$$\frac{\partial H}{\partial u_1} = -\lambda_1 S + \lambda_2 S + C_4 u_1 = 0 \Rightarrow u_1^* = \frac{(\lambda_1 - \lambda_2)S}{C_4}$$

$$\frac{\partial H}{\partial u_2} = -\lambda_5 I_s + \lambda_6 I_s + C_5 u_2 = 0 \Rightarrow u_2^* = \frac{(\lambda_5 - \lambda_6)I_s}{C_5}$$

Optimal control simulation for the $SVLI_a I_s TRD$ model

The characteristics of Table 1 were utilized to develop an optimal control model in MATLAB. The weight constants utilized for the optimal control issue are as follows: $C_1 = 1, C_2 = 1, C_3 = 1, C_4 = 100, C_5 = 100$. The optimality system was solved iteratively using forward and backward difference approximations [28] within the time interval of $[0, 30]$. Figure 5 depicts the differences in groups that are vulnerable, immunized, symptomatic and asymptomatic infected, treated, recovered, and deceased, both with and without control measures. This diagram illustrates that the implementation of controls leads to an increase in the populations of those who are infected but exhibit no symptoms, those who are infected and display symptoms, and those who are receiving treatment. Conversely, the populations of individuals who are vulnerable to infection, those who have been vaccinated, and those who have recovered from the infection fall. Figure 6 displays the most favorable control profile for u_1 and u_2 . Figure 7 illustrates that when the weight constants grow, the cost of control also increases, leading to a decrease in the number of control options. The simulation findings demonstrate the efficacy of appropriate control measures in reducing the number of illnesses.





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CONCLUSION

An epidemiological model for influenza A (H1N1) is developed and analyzed using vaccination and treatment methods. The immunization is only administered to individuals who are susceptible to the disease, and its effectiveness is not guaranteed. The model's solution is proven to be positive and bounded, and the fundamental reproduction number is calculated. An analysis is conducted on the stability of the disease-free equilibrium, both at a local and global level. Our analysis indicates that higher rates of vaccination and treatment lead to a decrease in the number of individuals who are infected, ultimately leading to the complete elimination of the disease. In addition, the proposed model encompasses the optimal control problem by integrating two types of controls: u_1 , which represents the vaccination of susceptible individuals, and u_2 , which enhances the treatment for sick individuals, resulting in their rapid recovery and transition to the recovered class. The numerical simulation findings demonstrate that the integration of vaccination and treatment strategies is highly efficient in reducing the overall number of infections.

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Table 1.Description of parameters of SVL I_a I_s TRD model

Parameter	Description	value	source	Sensitive indices
Π	Recruitment rate	15	Zhou, X. et.al.,[17]	1.0000
β	Disease transmission rate	0.000471	Estimated	0.9696
η	Rate at which susceptible individuals are vaccinated	0.01	Zhou, X. et.al.,[17]	-0.4819
ϕ	Rate of immunity loss	0.008	Zhou, X. et.al.,[17]	0.1554
ζ	Adjustment factor of asymptomatic infected population	0.3	Mathur. KS[18]	0.1953
ϱ	Adjustment factor of symptomatic infected population	0.3	Mathur. KS[18]	0.3047
α	Proportion of exposed population	0.5	Goswamiet. al.,[19]	-0.3396
σ	Conversion rate from exposed to infected population	0.8	Goswamiet. al.,[19]	0.1454
θ	Rate at which asymptomatic individuals becomes symptomatic	0.0376	Estimated	0.2982
κ	Rate at which symptomatic individuals joined into hospitals	0.1	Sariet.al.,[20]	-0.3606
γ_v	recovered rate during or after the vaccination	0.04	Kumar, K. A.,et. al.,[21]	-0.8200
γ_a	Rate at which asymptomatic infected individuals getting recovered	0.032	Goswamiet. al.,[19]	-0.7451
γ_t	Rate at which treatment individuals getting recovered	0.02	Hsu, S.B., et.al.,[11]	-





δ_s	Mortality rate of symptomatic infected individuals	0.04	Hsu, S.B., et.al.,[11]	-0.1801
δ_t	Mortality rate of hospitalized individuals	0.02	Hsu, S.B., et.al.,[11]	-
δ	Natural death rate	0.01	O. Diekmann, J. A., et. al [22]	-0.3141

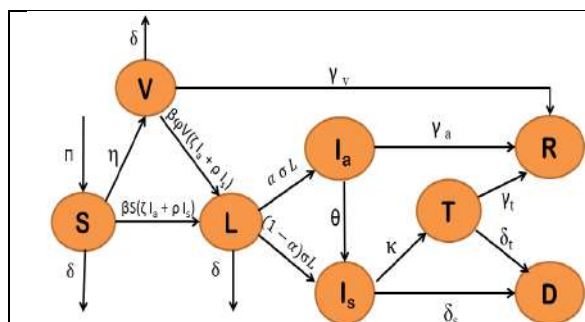


Fig.1 Schematic diagram of SVLIaIsTRD model

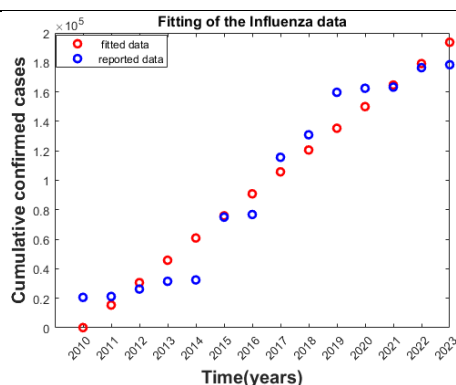


Fig.2 SVLIaIsTRD model fitting to (a) cumulative confirmed cases

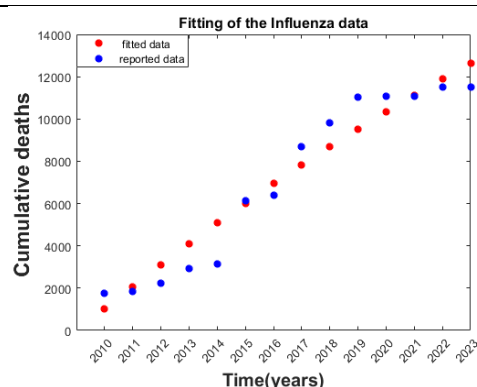
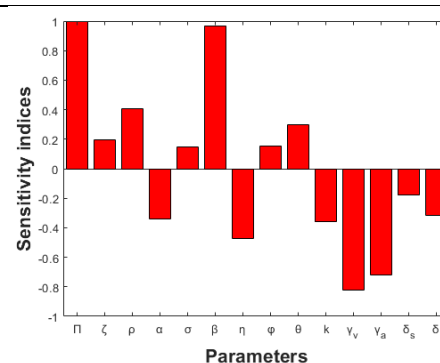
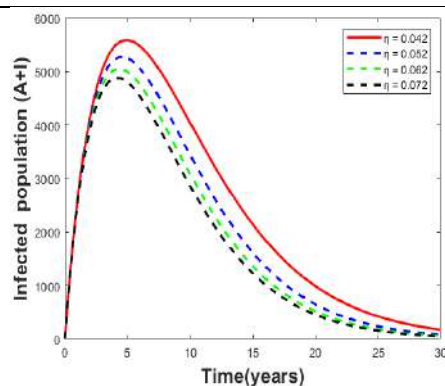
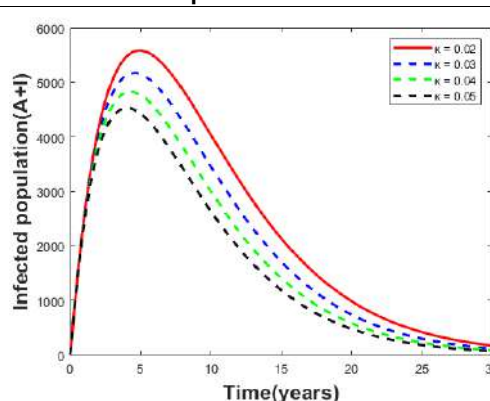


Fig.2 (b) cumulative deaths

Fig.3 Sensitivity indices of R_0 with respect to various parametersFig.4 a) Effect of vaccination rate (η) on infected populationFig. 4 b) Effect of treatment rate (κ) on infected population.



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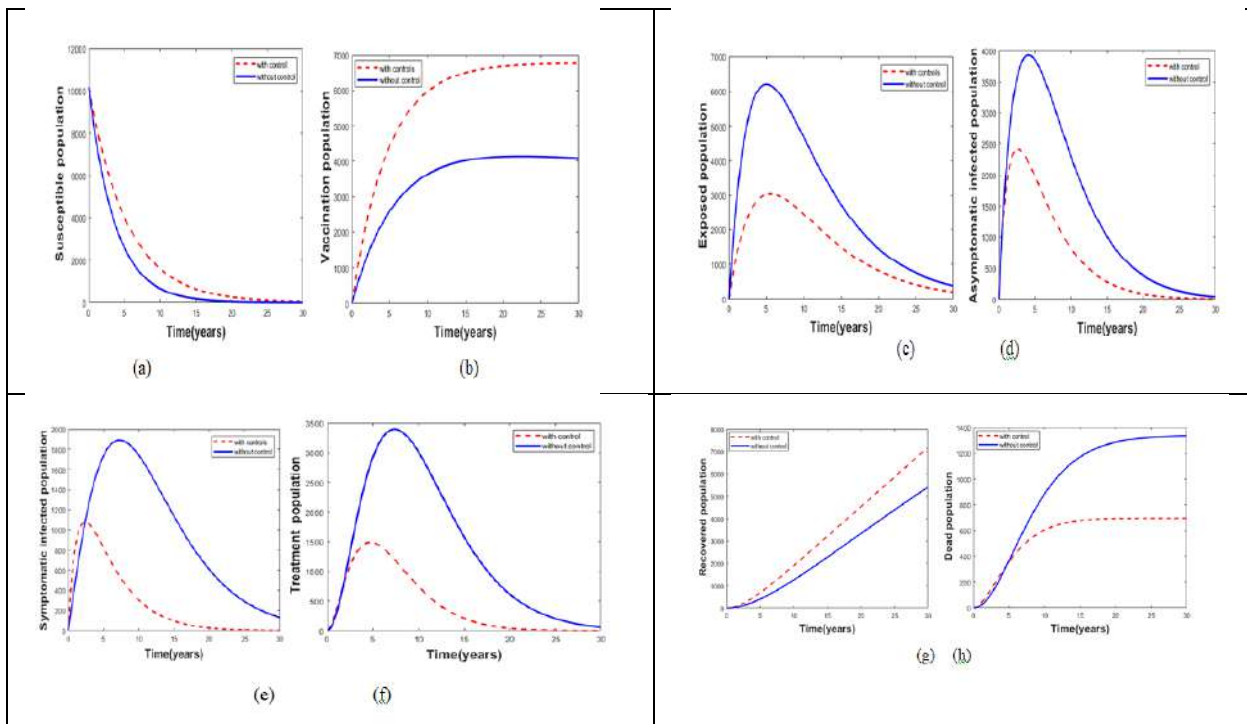


Fig.5 Variations of populations with control and without control

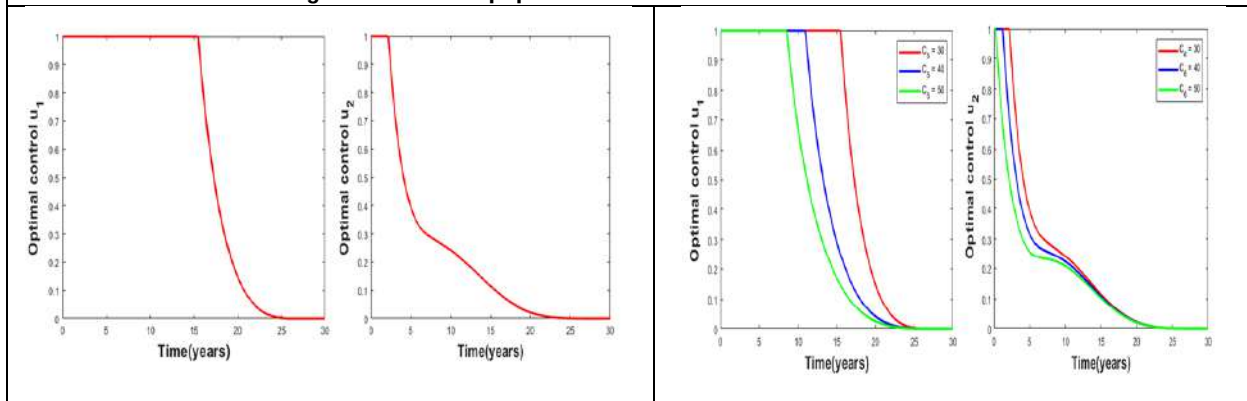


Fig.6 Plots of optimal control variables u_1 and u_2

Fig.7 Optimal control profile u_1 and u_2 for different costs of C_5 and C_6 .





Eco-Friendly Beauty : A Review of Herbal Cosmetics

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ABSTRACT

Herbal cosmetics have become very popular recently because they are safe for the skin, natural, and environmentally friendly. These products improve skin health and appearance by utilising the medicinal qualities of plants instead of artificial chemicals. With an emphasis on their biological activities, cosmetic applications, and evidence-based advantages, this review aims to examine a variety of herbs with cosmetic uses. In the context of their active ingredients, advantages, and formulations in skincare, haircare, and other cosmetic products, about 56 plants from various research articles are examined in this review.

Keywords: Herbal Cosmetics, Natural Products, Herbal Products, Eco-friendly beauty

INTRODUCTION

Herbal cosmetics have become increasingly popular as consumers seek safer and more sustainable alternatives to synthetic beauty products. These cosmetics are formulated using natural plant-based ingredients known for their therapeutic and cosmetic properties. The global shift toward herbal products is largely driven by concerns over the potentially harmful effects of chemicals and synthetic substances in conventional cosmetics, as well as a growing preference for products that align with eco-friendly and wellness-oriented lifestyles [1]. Herbal cosmetics not only promise safety and minimal side effects but also claim to offer numerous skin benefits, including anti-ageing, anti-inflammatory, and moisturizing effects, making them a viable alternative to chemical-laden beauty products. Herbal ingredients such as aloe vera, turmeric, and green tea have been used in traditional medicine for centuries due to their proven therapeutic effects on the skin. Aloe vera, for example, is widely recognized for its soothing, moisturizing, and healing properties, especially in the treatment of sunburns and dry skin [2]. Similarly, turmeric,



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with its antioxidant and anti-inflammatory properties, has become a key ingredient in skincare formulations aimed at treating acne and promoting even skin tone [3]. Green tea, rich in polyphenols, is a well-documented antioxidant that helps fight oxidative stress and reduce the visible signs of ageing, making it a popular inclusion in anti-ageing and rejuvenating skincare products [4]. Despite the growing demand for herbal cosmetics, several challenges remain in the industry. These include the standardization of herbal ingredients, ensuring product safety, and addressing the risk of allergic reactions to certain plant-based substances. Furthermore, there is a need for more scientific research to validate the efficacy of these products and provide concrete evidence of their long-term benefits [5]. Nevertheless, the herbal cosmetics market continues to expand, driven by consumer demand for natural, sustainable, and health-conscious beauty solutions. The development of new formulations and innovations in herbal product extraction techniques holds great potential for the future of this industry. This review aims to explore the scientific evidence behind herbal cosmetic ingredients, their efficacy, and the environmental benefits of using plant-based alternatives in the beauty industry. By analysing current trends and challenges, this review article provides a comprehensive overview of the plants that are commonly used in herbal cosmetics in India.

METHODOLOGY

The review method for this article involves a systematic approach that includes comprehensive literature searches, data extraction, and critical analysis of scientific studies. Research is conducted using reputable databases such as PubMed, Science Direct, and Google Scholar, focusing on peer-reviewed articles that discuss the chemical composition, therapeutic properties, and efficacy of herbal ingredients used in cosmetic formulations [6]. The review typically includes studies on popular plant-based ingredients like aloe vera, turmeric, and neem, examining their antioxidant, anti-inflammatory, and antimicrobial effects. [7] Articles are selected based on criteria such as relevance to the topic, publication date, and clinical or consumer efficacy findings, providing an in-depth understanding of the benefits, safety, and sustainability of herbal cosmetics compared to traditional chemical-based products. The results of the current review are presented in Table

Key Benefits of Herbal Cosmetics

- Synthetic chemicals are more likely to cause allergies or skin irritation than natural, plant-based ingredients.
- Skin and hair are nourished and protected by the vitamins, minerals, and antioxidants found in herbal products.
- Since herbal cosmetics use natural, renewable resources, they are usually more environmentally friendly.
- Moisturising, anti-inflammatory, antimicrobial, and anti-ageing qualities are multifaceted benefits that many herbs provide.

RESULTS AND DISCUSSIONS

A thorough examination of plants that are commonly used in India as herbal cosmetics in this review found a wide range of plants with various bioactive compounds that support their anti-ageing, skincare, and haircare qualities. *Aloe vera*, tulsi (*Ocimum sanctum*), neem (*Azadirachta indica*), *Hibiscus rosa-sinensis*, saffron (*Crocus sativus*), and turmeric (*Curcuma longa*) are among the plants that have long been prized in traditional medicine for their medicinal and aesthetic properties. The plants that are mostly used for cosmetic purposes are members of different plant families, and their parts - leaves, flowers, seeds, roots, and stems are used to make a variety of cosmetic products, including face masks, oils, creams, and lotions. The plants reviewed in this study have a variety of active substances, such as flavonoids, alkaloids, saponins, essential oils, and antioxidants, which help to hydrate, cleanse, and revitalise the skin and hair. For example, the essential oils of rose (*Rosa damascena*) aid in preserving skin elasticity and moisturising the skin, while the phenolic compounds in turmeric and tulsi have anti-inflammatory and antioxidant qualities. The plants identified in this study are not only integral to the Ayurvedic system but also have a growing presence in the global beauty market due to their natural, effective, and less harmful alternatives to synthetic cosmetics (Rani et al., 2019). The wide range of plants used, including well-known ones like Neem and Aloe vera, as



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well as lesser-known species such as *Bacopa monnieri* and *Bhringraj*, reflects the diversity of therapeutic uses found in traditional cosmetic practices. Due to their natural, safe, and effective substitutes for synthetic cosmetics, the plants in this study are not only integral to the Ayurvedic system but are also becoming more and more popular in the global beauty market in recent days [64]. The bioactive substances such as antioxidants, vitamins, and minerals found in these plant species have been scientifically proven to promote skin regeneration, increase suppleness, and guard against environmental damage [65]. As an example, Neem's antibacterial qualities are well-known for treating acne and promoting skin healing, while *Aloe vera* can hydrate and calm irritated skin is well-established [66]. Many of these plants, such as turmeric and saffron, are also well-known for their anti-ageing qualities, which makes them useful components of skin-brightening and anti-wrinkle products [67]. In addition to lowering oxidative stress, the antioxidant qualities of turmeric and tulsi also promote the synthesis of collagen, which improves the suppleness and smoothness of the skin [68]. Furthermore, the hair care advantages of fenugreek and hibiscus highlight the plants' versatility in herbal cosmetics. While fenugreek is high in proteins that nourish hair follicles, hibiscus's flavonoids and amino acids help to strengthen hair and prevent premature greying of hair [69].

Challenges in Herbal Cosmetics

- Variations in the quality of raw materials and the absence of standardised production techniques might impact the consistency of the final herbal product.
- Since herbal components don't contain artificial preservatives, their shelf lives are frequently lower.[70].

Future Prospects

Emerging technologies, such as nanotechnology and green chemistry, offer opportunities to enhance the stability and efficacy of herbal cosmetics. Additionally, consumer education on the benefits and limitations of herbal products can foster trust and drive adoption.

CONCLUSION

In conclusion, the plants reviewed in this study present substantial potential for use in herbal cosmetics, offering a range of therapeutic benefits for skin and hair care. These plants provide natural, eco-friendly alternatives to synthetic chemicals, aligning with the growing consumer preference for organic and holistic beauty products. However, to fully unlock the potential of these plants, further scientific studies, including clinical trials and pharmacological research, are necessary to validate their cosmetic claims and ensure their safety for long-term use. With further exploration and integration into the beauty industry, these plants contribute to a more sustainable and health-conscious approach to skincare and hair care. In future the herbal cosmetics will represent a promising segment in the beauty and personal care industry.

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Table – 1: Common plant species used as Herbal cosmetics

Sl.No	Botanical Name of the Plant	Common Name	Parts Used	Uses	References
1	<i>Acacia concinna</i>	Shikakai	Pods	Natural hair cleanser; promotes hair growth; and prevents dandruff.	[8]
2	<i>Aloe vera</i>	Aloe	Leaves	Moisturizes and soothes skin; treats sunburn; acts as a natural conditioner for hair.	[9]
3	<i>Azadirachta indica</i>	Neem	Leaves	Treats acne; and has antibacterial and antifungal properties.	[10]
4	<i>Bacopa monnieri</i>	Brahmi	Whole plant	Promotes hair growth; strengthens hair roots; and improves scalp health.	[11]
5	<i>Beta vulgaris</i>	Beetroot	Root	Brightens skin; natural blush; improves skin hydration; natural red pigment and it provides hydration and nourishment to dry lips.	[12]
6	<i>Calendula officinalis</i>	Calendula	Flowers	Soothes irritated skin; heals minor cuts.	[13]
7	<i>Camellia sinensis</i>	Green Tea	Leaves	Antioxidant, anti-ageing, protects skin against UV radiation and reduces skin inflammation.	[14]
8	<i>Carica papaya</i>	Papaya	Fruit	Exfoliates skin; brightens complexion.	[15]
9	<i>Chrysopogon zizanioides</i>	Vetiver	Roots	Cools and soothes skin; treats acne; used as perfume.	[16]
10	<i>Cicer arietinum</i>	Gram Flour	Seeds	Natural cleanser; used in face packs.	[17]





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11	<i>Citrus limon</i>	Lemon	Fruit	Treats acne; lightens pigmentation.	[18]
12	<i>Citrus sinensis</i>	Orange	Peel	Natural exfoliant; brightens skin.	[19]
13	<i>Cocos nucifera</i>	Coconut	Oil from kernel	Moisturizes skin; nourishes hair; used in massage oils.	[20]
14	<i>Coriandrum sativum</i>	Coriander	Seeds	Treats blemishes; balances skin tone.	[21]
15	<i>Crocus sativus</i>	Saffron	Stigmas	Enhances skin complexion; reduces pigmentation; used in face packs.	[22]
16	<i>Cucumis sativus</i>	Cucumber	Fruit	Hydrates skin; reduces puffiness around eyes.	[23]
17	<i>Curcuma longa</i>	Turmeric	Rhizome	Improves complexion; reduces blemishes; anti-inflammatory properties.	[24]
18	<i>Daucus carota</i>	Carrot	Root	Promotes skin regeneration and nourishes the lips. It also helps to lighten dark lips.	[25]
19	<i>Eclipta alba</i>	Bhringraj	Leaves	Strengthens hair roots; prevents hair loss and dandruff.	[26]
20	<i>Emblica officinalis</i>	Indian Gooseberry	Fruit	Strengthens hair; prevents premature greying; enhances hair lustre.	[27]
21	<i>Glycyrrhiza glabra</i>	Licorice	Roots	Brightens skin; reduces dark spots; used as face masks and creams.	[28]
22	<i>Hibiscus rosa-sinensis</i>	Hibiscus	Flowers	Promotes hair growth; natural conditioner for hair; prevents hair fall.	[29]
23	<i>Indigofera tinctoria</i>	Indigo	Leaves	Used as Herbal kajal for eyes for its rich blue-black colour. It is also applied as a hair dyes.	[30]
24	<i>Lavandula angustifolia</i>	Lavender	Flowers	Soothes skin; reduces acne.	[31]
25	<i>Lawsonia inermis</i>	Henna	Leaves	Natural hair dye; strengthens hair; used as mehendi.	[32]
26	<i>Linum usitatissimum</i>	Flaxseed	Seeds	Improves skin texture; moisturizes and nourishes dry skin.	[33]
27	<i>Matricaria chamomilla</i>	Chamomile	Flowers	Calms skin irritation; anti-inflammatory.	[34]
28	<i>Melaleuca alternifolia</i>	Tea Tree	Leaves	Treats acne; and has antibacterial properties.	[35]
29	<i>Mentha arvensis</i>	Mint	Leaves	Refreshes skin; treats acne.	[36]
30	<i>Mentha piperita</i>	Peppermint	Leaves	Cooling reduces inflammation and soothes acne.	[37]
31	<i>Mesua ferrea</i>	Nagkesar	Flowers	Reduces blemishes; brightens skin tone.	[38]
32	<i>Moringa oleifera</i>	Moringa	Leaves, Seeds, and Oil	Hydrates skin, fights wrinkles, and provides antioxidant protection.	[39]
33	<i>Murraya koenigii</i>	Curry Leaves	Leaves	Promotes hair growth; treats premature grey hair and dandruff.	[40]
34	<i>Musa paradisiaca</i>	Banana	Fruit	Conditions hair; moisturizes skin.	[41]
35	<i>Nardostachys</i>	Jatamansi	Rhizome	Promotes hair growth; and prevents	[42]





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	<i>jatamansi</i>			premature greying.	
36	<i>Ocimum sanctum</i>	Basil	Leaves	Purifies skin; reduces blemishes; and has antibacterial properties.	[43]
37	<i>Ocimum tenuiflorum</i>	Holy Basil	Leaves	Clears skin; antibacterial properties.	[44]
38	<i>Origanum vulgare</i>	Oregano	Leaves	Antioxidant properties; anti-aging	[45]
39	<i>Panax ginseng</i>	Ginseng	Root	Anti-ageing revitalizes skin, and promotes blood circulation.	[46]
40	<i>Persea americana</i>	Avocado	Fruit (pulp)	Provides deep nourishment and hydration to the lips. It is also applied around the eyes for its anti-ageing properties.	[47]
41	<i>Petroselinum crispum</i>	Parsley	Leaves	Reduces puffiness; brightens skin.	[48]
42	<i>Punica granatum</i>	Pomegranate	Seeds	Antioxidant properties; promote skin regeneration and elasticity.	[49]
43	<i>Rosa indica</i>	Rose	Petals	Tones skin; provides natural fragrance. Rose water is also used in eye care to reduce puffiness and irritation.	[50]
44	<i>Rosmarinus officinalis</i>	Rosemary	Leaves	Stimulates hair growth; improves scalp health.	[51]
45	<i>Rubia cordifolia</i>	Manjistha	Roots	Improves skin complexion; purifies blood.	[52]
46	<i>Salvia officinalis</i>	Sage	Leaves	Reduces hair fall; treats oily skin.	[53]
47	<i>Santalum album</i>	Sandalwood	Heartwood	Improves skin texture; used in face packs; natural fragrance.	[54]
48	<i>Sapindus mukorossi</i>	Reetha	Fruit	Natural shampoo; cleanses the scalp; and adds shine to hair.	[55]
49	<i>Saraca asoca</i>	Ashoka	Bark	Enhances complexion; reduces pigmentation and blemishes.	[56]
50	<i>Sesamum indicum</i>	Sesame	Seeds	Moisturizes dry skin; has anti-ageing properties; is used in oil massages.	[57]
51	<i>Symplocos racemosa</i>	Lodhra	Bark	Treats acne; tightens skin; used in skincare preparations	[58]
52	<i>Tagetes erecta</i>	Marigold	Flowers	Antiseptic properties; enhance skin health.	[59]
53	<i>Thymus vulgaris</i>	Thyme	Leaves	Antimicrobial properties; treats skin infections.	[60]
54	<i>Trigonella foenum-graecum</i>	Fenugreek	Seeds	Strengthens hair; conditions scalp; treats dandruff.	[61]
55	<i>Withania somnifera</i>	Ashwagandha	Roots	Anti-ageing properties; rejuvenates skin.	[62]
56	<i>Zingiber officinale</i>	Ginger	Rhizome	Improves skin elasticity; reduces scars.	[63]





RESEARCH ARTICLE

Petrogenesis and Geochemistry of Dolerite Dykes in Ranipet District, Northern Part of Southern Granulite Terrain, Tamil Nadu, India

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ABSTRACT

The current research focuses on a major dykes located in the Ranipet district, which exhibits WSW-ENE trending dykes that intruded the hornblende-biotite gneiss, with gabbroic diorite and granite gneiss. The dolerite in this area exhibits a typical dolerite composition with significant alteration such as chloritization and sericitization. From a mineralogical perspective, the rock contains plagioclase laths, anhedral to euhedral clinopyroxene with basal cleavage, and quartz minerals. Opaque minerals such as ilmenite and magnetite crystals are interspersed among the major minerals and display altered boundaries. Texturally, the rock exhibits a sub-ophitic and intermediate gabbroic (granular) texture. The TAS diagram illustrates that the dykes are situated within the basalt, basalt andesitic, and rhyolitic fields (highly sericitized dolerite). The host and other associated rocks fall within the sub-alkaline field. The bivariate analysis of the dolerite under study reveals a positive relationship with SiO₂, CaO, Na₂O, K₂O, and P₂O₅, while displaying a negative correlation with TiO₂, Fe₂O, and Al₂O₃. Both the AFM and Jensen plots indicate that the dolerite samples are located in the tholeiitic field with Fe enrichment and a High Fe tholeiitic character respectively. The primitive mantle diagram demonstrates the depletion of Nb, P, and Ti, suggesting potential crustal interaction during the emplacement process. The Chondrite normalized plot for the dolerite exhibits an enrichment of LREE and a slight depletion of HREEs, indicating an OIB character. Tectonically, the dolerites were emplaced in continental and alkaline arc OIB settings with E-MORB affinity. The dolerites are derived from garnet lherzolite/garnet peridotite field indicating a deep mantle source.

Keywords: Dolerite, Mafic dyke, Ranipet, Petrogenesis, Geochemistry.





INTRODUCTION

Peninsular mafic dykes in India reveal the subcontinent's tectonic evolution, and intrusions provide a window through which to observe mantle evolution (Tarney, 1992; Hall and Hughes 1993). The dimensions and orientations of the mafic dyke intrusions in the Indian subcontinent vary (Naqvi, 2005; Srivastava and Gautam, 2008). In peninsular India, mafic dykes, particularly dolerite intrusions, are large-scale formations exposed in stabilized cratons and terrains (Dash et al., 2013; Pivarunas et al., 2019; Srivastava et al., 2019, 2021). In the northern portion of the Southern Granulite Terrain (SGT), the dolerite dykes are extensively exposed and pertain to discrete crustal-scale shear zones (Collins et al., 2014; Pandit et al., 2016). The mafic dyke is exposed to basement rocks such as hornblende biotite gneiss, charnockite gneiss, granitic gneiss, and diorite intrusion as part of the southern granite terrain in the northern granulite terrain. In the northern parts of the Archean to Proterozoic crustal blocks of the SGT, a number of mafic dyke intrusions are observable. According to Radhakrishna and Joseph (1998), the dolerite dykes in the Tamil Nadu regions of Tiruvannamalai and Dharmapuri have Fe-rich tholeiitic compositions with enrichment in large-ion lithophile elements (LILE) and light rare-earth elements (LREE), along with depletion of Nb and Ta. The geochemical characteristics align with the derivation from a source of enriched lithospheric mantle, potentially impacted by previous Archean crustal building events. This mafic dyke exposure in Tamil Nadu's northern Ranipet district is most likely the southern edge of the Cuddapah basin dykes. The dykes in the northern part of Tamil Nadu were emplaced during the Proterozoic period adjacent to the Cuddapah basins within the peninsular gneissic complex from multi-episode injections, probably single to various magma sources with crustal interactions (Drury, 1984; Murthy et al., 1987; Sankar et al., 2015). The Cuddapah mafic dykes adjacent to the Dharwar eastern margin recognized that the dyke swarm was older than 2082 Ma and was emplaced around the Cuddapah basin (Kumar et al., 2015). The dykes in this study area fall at the margin of the Fermor line or orthopyroxene isograd (Fermor, 1936; Drury et al., 1984). The orthopyroxene isograd cannot host the dolerite dykes in this region, but occasionally exposed charnockitic enclaves were identified in this region. The western and southern borders of the Cuddapah Basin open up onto the eastern edge of the Dharwar Craton dykes. Chittoor and Anantapur are affected by the dolerite intrusion with an OIB nature that is present in the southern edge of the Cuddapah Basin (Ramamohana Rao et al., 1986). Mafic to ultramafic dolerite intrusion with a tholeiitic to highly dolerite composition is made possible by the OIB created by the rifting activity (Bas, 1971). The current study outlines how the current study area connects to adjacent dolerite intrusions in the southern margin of the Cuddapah Basin and the eastern margin of the Dharwar craton. It also discusses the nature of the intrusion, mineralogical character, geochemical nature, and tectonic settings of dolerite intrusion in the Ranipet district.

Geological setting

The mafic dykes, particularly the dolerite dykes, in Peninsular India have been extensively studied (Ernst and Srivastava, 2008; Pati et al., 2008; Pratheesh et al., 2011; Dash et al., 2013; Radhakrishna et al., 2013; Pivarunas et al., 2019; Kumar et al., 2020; Srivastava et al., 2008, 2021, 2022; Ramachandran et al., 2023a, b; Datta et al., 2023; Ashutosh et al., 2024). In Tamil Nadu, the northernmost intrusion within the Southern Granulite Terrain (SGT) comprises dolerites in the Ranipet area. These dolerite dykes extend into the Chittoor district of Andhra Pradesh, spreading along an east-west orientation through Archean–Proterozoic rocks. Predominantly dolerites, these intrusions occasionally include gabbroic dykes. The Ranipet dolerite dykes and the Chittoor dolerite dykes share the same orientation, with more extensive exposure in Chittoor compared to Ranipet. The southern tip of the Cuddapah Basin also extends into the Chittoor district, characterized by the peninsular gneissic complex and granitic plutons. The paleo-tectonic environment of Anantapur–Chittoor basic dykes was studied by Ramamohana Rao et al. (1986), indicating formation in Oceanic Island Basalt (OIB) settings linked to hotspots. The Chittoor dykes, in contrast, are associated with subduction-related processes, evidenced by their low TiO₂ content and Nb/La ratio of ~0.40 (Sankar et al., 2014). Situated south of the Cuddapah basin sedimentation (Halls, 1982; Drury, 1984), the Chittoor dykes indicate that the mafic intrusion in Ranipet might predate the Cuddapah basin sedimentation and could originate from the same source as the Chittoor dolerite dykes. Additionally, the dolerite dykes in this region are likely in contact with the eastern Dharwar craton dykes.



Rameshkumar *et al.*,**Field Relationship**

The dolerites in the study area exhibit east-west trending intrusions emplaced within hornblende biotite gneissic rock (Fig. 2). These dolerites, located in the Ranipet district, are characterized by their dark green to greenish-black color. In hand specimens, the dolerites display massive, fine to medium grains, with finer textures observed at the chilled margins and medium to coarser grains towards the center of the dykes. The color of the dolerites is typically greenish-grey. The dykes present a linear and sometimes crooked contact with the host rock. The hornblende biotite gneiss contains amphibolite xenoliths aligned parallel to the gneissic foliation of the host rock. The dykes exhibit numerous fractures and joints with varying orientations. The hornblende biotite gneissic host rock is leucocratic, predominantly comprising feldspar and quartz, with hornblende and biotite minerals also present. The host rock is intruded by pegmatite and quartz veins, which show evidence of deformation displacements. These vein intrusions occurred prior to the emplacement of the dolerite dykes in the region. The pegmatite intrusions are noted for their medium to coarse grains in some locations, attributed to intermediate cooling rates within the hornblende biotite gneiss. The alignment of hornblende and biotite minerals in the host rock is almost perpendicular to the dolerite dykes, which crosscut the gneissic foliation. Additionally, granitic gneiss and gabbroic diorite rocks are identified as part of the intrusive suite within the peninsular gneissic complex. The structural and compositional characteristics of these rocks provide insights into the geological history and tectonic processes that have shaped this region. The east-west orientation of the dolerite dykes suggests a significant tectonic influence, possibly related to regional stress fields during their emplacement. The presence of amphibolite xenoliths and the varied grain sizes within the host rock indicate a complex cooling history, while the fractures and joints reflect subsequent tectonic activities. Moreover, the relationship between the dolerite dykes and the hornblende biotite gneissic host rock reveals important information about the timing and sequence of geological events. The pre-existing pegmatite and quartz veins suggest multiple phases of intrusion and deformation, highlighting the dynamic geological environment of the region. The alignment of hornblende and biotite minerals perpendicular to the dykes indicates the relative ages of the intrusions and the orientation of the stress fields during their emplacement. This geological setting, with its diverse rock types and structural features, provides a valuable context for understanding the tectonic evolution of the Southern Granulite Terrain and its relationship with adjacent geological units like the Cuddapah Basin and the eastern Dharwar craton.

Petrography

A total of 61 fresh rock chips from medium and coarse-grained dolerite are collected. These samples are specifically taken from the center of dykes for detailed textural analysis. The samples are then sent to Continental Instruments in Lucknow for thin section production. Once the thin sections are prepared, the next phase involves studying the petrographic characteristics using a Leica DM2700 P petrological microscope at the Department of Geology, Periyar University, India. This microscope is equipped with the Leica Application Suite, which aids in analysing the mineral composition and texture of the dolerite samples. The photomicrographs of Fig 3a) show the subophitic texture of dolerite rock exhibit plagioclase laths and pyroxene and opaque minerals. b) –c) Photomicrograph showing medium grain plagioclase and pyroxene mineral shows subophitic and intersertal texture with granophyric intergrowth. d-g and i) Photomicrograph of the XPL sections shows dolerite mineralogy, where a sub-ophitic is present in the rock. h) shows microcrystalline groundmass with microphenocryst of plagioclases, sample collected from the chilled margin of the dyke. j)–l) Photomicrograph shows quartz and feldspar as essential, and biotite and hornblende present as accessory minerals in the hornblende biotite gneiss. A few opaque minerals were present in the rock with mafic minerals.

Analytical Techniques**Whole-rock geochemistry**

The samples were ground to a size of 63 μ using steel and agate mortars. Subsequently, 17 pulverized samples were dispatched to Activation Laboratory Limited in Canada for Lithogeochemistry and Whole Rock Analysis. The samples were examined under the package code 4Litho (WRA+ICP), requiring 5g of the pulverized sample to meet the criteria of 95% passing through 105 microns (μ m). The fusion process, which involves lithium metaborate/tetraborate fusion, is carried out by a robotic system at Actlabs. Following fusion, the resulting molten



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bead is swiftly digested in a dilute nitric acid solution to ensure complete dissolution of the entire sample. This aggressive fusion technique is crucial for the solubilisation of major oxides such as SiO_2 , refractory minerals (e.g., zircon, sphene, monazite, chromite, and gahnite), REE, and other high field strength elements. Although high sulphide-bearing rocks may necessitate different treatment, they can still be effectively analyzed. The analysis is conducted using ICP-OES and ICP-MS. In samples with exceptionally high Ba concentrations (> 5%), Eu determinations are considered semi-quantitative. Major oxides and selected trace elements (4B) are analyzed on an ICP instrument. Calibration is carried out using 14 meticulously prepared USGS and CANMET-certified reference materials.

Whole-rock geochemistry

The geochemical composition of the dolerite, hornblende biotite gneiss, granitic gneiss, and amphibolite rocks is presented in Table 2. The dolerite contains 51.57-55.95% SiO_2 and 4.66-8.79% MgO. The CIPW norm calculated for total iron (Fe_2O_3^T) for all samples indicates quartz normative (Table 2). Additionally, quartz normative tholeiites for dolerite dykes have been identified in certain areas of Chittoor, Anantapur, and Mahbubnagar districts (Sarma, 1991; Reddy 1991). The mafic index character of the dolerite dyke was determined using the Harker binary diagram based on MgO vs Major elements (Fig 6) and Trace (Fig 7) plots. The bivariate plot of MgO vs SiO_2 shows a negative correlation as MgO increases with decreasing SiO_2 . Similarly, the bivariate plot of MgO vs Al_2O_3 , Na_2O , and TiO_2 also shows a negative correlation, while the plot of CaO , P_2O_5 , and FeO^T vs MgO shows a positive correlation. The positive correlation of CaO vs MgO suggests clinopyroxene fractionation during crystallization. The Mg\# ($100\text{Mg}/(\text{Mg}+\text{Fe}^T)$) ranges from 34.60 to 56.97, indicating mafic characteristics. The total alkali versus SiO_2 (TAS) diagram (Fig 4) shows that the dolerite dykes fall within the basalt and basalt andesitic field. The AFM ($\text{A}=\text{Na}_2\text{O}+\text{K}_2\text{O}$; $\text{F}=\text{Fe}_2\text{O}_3^T$; $\text{M}=\text{MgO}$) plot of Irvine and Baragar (1971) diagram (Fig 8a) shows that dolerite, amphibolite, and gabbroic diorite rocks fall within the tholeiite series field, with dolerites exhibiting a prominent iron-enrichment trend. The triangular cation plot by Jensen (1976) illustrates the distribution of dolerite and amphibolite samples in the high-Fe tholeiite basalt field, along with one sample in the komatiite basalt field. In contrast, the bivariate classification diagram developed by Miyashiro (1974) (SiO_2 vs FeO/MgO) displays the positioning of dolerite samples in the calc-alkaline series, with one sample in the tholeiite series.

The amphibolite sample was also positioned within the tholeiite series. Due to the elevated SiO_2 content and high FeO/MgO ratio, the granitic gneiss samples are located within the tholeiite series field (Miyashiro, 1974). The Nb/Y vs Zr/TiO_2 binary diagram, as proposed by Winchester & Floyd (1977), indicates that the dolerite samples fall within the subalkaline basalt and andesitic/basalt field. Specific trace elements are utilized to track the fractionation process of magma. By plotting trace and REE elements against MgO, the genetic nature of the dolerite dykes can be distinguished. In Figure 7, trace elements are plotted against MgO, revealing a positive correlation for Cr, Ba, Ni, Mg, Sr, Rb, and $\text{K}_2\text{O}/\text{Na}_2\text{O}$, while Y, Ce, La, Zr, and A/CNK ratio exhibit a slightly negative correlation. The positive and negative correlations of elements with MgO are indicative of compatible elements that align with compatible and incompatible elements. In the bivariate plot against MgO, compatible elements display a positive correlation, whereas incompatible elements exhibit a negative correlation as the magma undergoes fractional crystallization from the parent magma. The trace element compatibility diagram for Ranipet dolerite dykes, based on the Primitive Mantle normalization method (Fig 9, Sun & McDonough, 1989), reveals positive enrichment of Ba, K, Pb, Sr, Nd, and negative anomalies of Nb, P, Zr, and Ti. The depletion of Ti in gabbroic diorite and hornblende biotite gneiss indicates an incompatible nature that cannot coexist with the minerals in the rock. Additionally, Th and U show a slight depletion pattern in all samples except one from the Venkatapuram area, where they exhibit slightly high spikes, suggesting a higher concentration compared to the other dolerite dykes. The low Th, U, and Sr content in the present study suggests that the dolerites evolved in an oceanic environment, with some dolerites exposed in continental settings. Furthermore, the granitic gneiss in the diagram shows a high positive enrichment of Th. Eu shows no or little anomaly in all dolerite samples. All studied dolerite dyke samples, other associated rock samples, OIB, E-MORB, and N-MORB samples (from Sun and McDonough, 1989) were normalized to Chondrite REE (Fig 9 below) for comparison, revealing sharply fractionated LREE enrichment pattern relative to HREE, with MREE showing a slightly inclined pattern, and one dolerite sample exhibiting a flat MREE pattern. Additionally, HREE (Tb-



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Lu) shows steep depletion with no appreciable or little anomaly of Eu, behaving like OIB. The low ratio of Nb/La (~0.03-0.40) and low levels of TiO₂ suggest an intrusion related to subduction. Nevertheless, the enrichment of LREEs and the depletion pattern of HREEs are characteristic of OIB, with the exception of one sample that exhibits behavior consistent with E-MORB, contradicting the typical OIB signature.

Tectonic Settings

The dolerite intrusions in the Ranipet district of Tamil Nadu and the southern border of Andhra Pradesh are part of the peninsular gneissic complex (PGC), which also includes hornblende biotite gneiss. Proterozoic dykes from the Cuddapah basin are found near the study area. Various tectonic setting diagrams were utilized to illustrate the emplacement settings of the dolerite dykes. In the ternary tectonic diagram by Pearce et al. (1977) using major oxides MgO-Fe₂O₃-T-Al₂O₃, dolerite samples and one amphibolite sample are categorized into Ocean Island and continental settings, while the host rock HBG falls under orogenic settings. The Zr-3*Y-Ti/100 ternary diagram (Fig 10b) by Pearce and Cann (1973) shows that all dolerite samples are located in the Within Plate Basalt region, except for one sample which falls under the MORB field. OIB and CONB (Within Plate Continental Basalt) are collectively referred to as WPB, characterized by tholeiitic and alkali basalt (Ramamohana Rao et al., 1986). The Zr-Ti plot (Pearce, 1982) illustrates the distribution of dolerites (Fig 11a) within the Island Arc Basalt and Within-Plate lavas field. The binary plot (Fig 11b) Ti vs V (Shervais, 1982) indicates that the dolerite samples fall within the Oceanic Flood Basalt (OFB) field with a Ti/V ratio ranging from 20-50. Another bivariate discrimination diagram (Fig 11c) Zr vs Zr/Y (Pearce and Norry, 1979) shows that most dolerite samples are located outside the field of Within-Plate Basalt (WPB), with one sample falling inside the WPB region. The Nb/Yb vs Th/Yb ratio discrimination diagram (Fig 11d, Pearce, 2008) reveals that dolerite samples align closely with the E-MORB array and trend from E-MORB to OIB. All tectonic discrimination diagrams indicate that the majority of dolerite samples cluster tightly, with the exception of one sample. The tectonic discrimination diagrams for dolerite dykes suggest an affinity with MORB and within-plate basalt, displaying OIB characteristics. However, the chemical variations in the basaltic magma of different environments are influenced by crustal interaction and partial melting of magma.

Petrogenesis

The La vs La/Sm plot (Figure 12a) demonstrates the fractional melting and partial melting trends during the evolution of the analyzed samples from the Ranipet dolerite. These trends indicate varying degrees of partial melting and fractional crystallization in the magma source. Meanwhile, the Sm vs Sm/Yb ratio plot (Zhao and Zhou, 2007) reveals that most samples are situated within the Garnet Peridotite field, with only one sample plotting close to the Spinel peridotite source, corresponding to a melting curve ranging from 5 to 10 degrees of partial melting (Figure 12b). Samples with high Sm/Yb ratios plotting in the Garnet Peridotite field indicate that they may have originated from a deep mantle source, where garnet is present as a residual phase. The elevated Sm/Yb ratios suggest that these rocks originate from a deep mantle source. Additionally, the La_(PM) vs La/Yb_(PM) plot (Figure 12c) shows that the dolerite samples predominantly fall within 3 to 5 % of melting curve in the Garnet lherzolite field, with the exception of one sample that plots within the Spinel lherzolite field. This distribution further supports the inference of a deep mantle origin, with varying degrees of partial melting and source characteristics influencing the geochemical signatures of the Ranipet dolerite samples. The La/Sm vs Sm/Yb plot (figure 12d, after Aldanmaz et al., 2000) shows that the samples plot in the spinel-garnet-lherzolite field within 1 to 5 % of melting curve. Here, the intermediate Sm/Yb ratios, indicating the presence of both spinel and garnet, suggesting a transitional depth for the dolerite samples.

CONCLUSION

The present study outlines the mineralogical, geochemical, tectonic conditions and petrogenesis for dolerite in the Ranipet district of Tamil Nadu. The present research identifies several factors, such as the doleritic composition of the collected dyke samples, the predominant presence of lath-shaped plagioclase and clinopyroxene in these rocks, and the minor amounts of opaque minerals. Additionally, the granophyric intergrowth is observed in the interstices of



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plagioclase minerals. The collected dolerite rock exhibits subophitic textures, while a few dykes display gabbroic texture with relict doleritic intergrowth. Geochemically, the dolerite rocks demonstrate quartz normative tholeiites with Fe enrichment. The TAS plot for dolerites indicates a basaltic-to-basaltic andesitic composition. Furthermore, the compatible elements exhibit a positive correlation with MgO. The primitive normalized diagram reveals positive enrichment of Ba, K, Pb, Sr, and Nd, as well as negative anomalies of Nb, P, Zr, and Ti. Eu shows no or little anomaly. The chondrite normalized diagram plot illustrates the enrichment of LREE and depletion of HREE pattern for dolerites relative to Ocean Island Basalt. The tectonic settings for the current dolerite samples indicate Island Arc Basalt, WPB character, suggesting that the dolerites were likely emplaced in the island arc and WPB settings with OIB and E-MORB affinity during fractionation of partial melting of magma. The petrogenesis plots suggest that the samples derived from the deep mantle source of garnet lherzolite field, where garnet remains as a residual phase.

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Table. 1. Shows the sample No/location, name of the rock, Lat/long and trend of the dyke.

S. No	Sample No	Location	Rock Name	Latitude	Longitude	Trend
1	VG40	Kodakkal	Amphibolite	13° 04' 00.9"	79° 24' 17.2"	-
2	VG11	Rendadi	Dolerite dyke	13° 04' 16.3"	77° 52' 16.6"	E-W
3	VG15	Kodakkal	Dolerite dyke	13° 04' 25.4"	79° 23' 11.8"	E-W
4	VG17	Kodakkal	Dolerite dyke	13° 04' 27.5"	77° 23' 11.8"	E-W
5	VG2	Rendadi	Dolerite dyke	13° 04' 04.7"	79° 21' 31.7"	E-W
6	VG31	Kodakkal	Dolerite dyke	13° 04' 49.5"	79° 24' 18.6"	E-W
7	VG32	Kodakkal	Dolerite dyke	13° 04' 49.5"	79° 24' 18.6"	E-W
8	VG5	Rendadi	Dolerite dyke	13° 04' 04.9"	79° 21' 30.8"	E-W
9	VG50	Venkatapuram	Dolerite dyke	13° 01' 40.0"	79° 24' 16.4"	NNE-SSW
10	VG60	Sengadu	Dolerite dyke	12° 56' 33.2"	79° 23' 43.6"	NNW-SSE
11	VG4	Rendadi	Gabbroic Diorite	13° 04' 04.6"	79° 21' 30.8"	-
12	VG51	Venkatapuram	Granitic gneiss	13° 01' 37.4"	79° 23' 56.5"	-
13	VG38	Kodakkal	Hornblende Biotite Gneiss	13° 03' 59.5"	79° 24' 27.8"	-
14	VG6	Rendadi	Hornblende Biotite Gneiss	13° 04' 04.6"	79° 21' 30.7"	-
15	VG63	Sengadu	Hornblende Biotite Gneiss	12° 56' 33.2"	79° 23' 43.9"	-
16	VG69	Sengadu	Hornblende Biotite Gneiss	12° 56' 36.1"	79° 23' 43.5"	-
17	VG34	Kodakkal	Trachy-dacite	13° 04' 29.1"	79° 24' 53.3"	-

Table. 2 Whole rock geochemical data for dolerite dykes and associated rocks from Ranipet district, Tamil Nadu. Fe₂O₃^T = Total Fe. DOL-Dolerite, TD-Trachy Dacite, HBG-Hornblende Biotite Gneiss, GG-Granitic Gneiss, AMP-Amphibolite.

Sample No	V G2	V G4	V G5	V G6	VG 11	VG 15	VG 17	VG 31	VG 32	VG 34	VG 38	VG 40	VG 50	VG 51	VG 60	VG 63	VG 69
Rock Name	D OL	T D	D OL	HB G	DO L	DO L	DO L	DO L	DO L	GG	HB G	A MP	DO L	GG	DO L	HB G	HB G
SiO ₂	55.95	53.71	54.02	64.85	53.11	54.23	54.33	54.45	54.45	73.1	68.3	47.85	51.57	65.48	53.17	70.96	73.42
Al ₂ O ₃	10.87	13.45	10.39	15.15	10.05	10.29	10.22	10.38	10.55	14.22	13.64	14.97	12.66	15.41	9.02	16.01	14.2
Fe ₂ O ₃ ^T	13.13	10.84	13.1	6.13	12.96	13.02	12.96	13.13	13.31	2.02	3.85	14.31	17.45	6.06	13.15	2.06	2.3
MnO	0.163	0.203	0.159	0.119	0.157	0.16	0.157	0.16	0.161	0.021	0.103	0.199	0.216	0.062	0.172	0.031	0.037
MgO	6.27	8.45	7.9	3.05	7.77	7.94	7.92	7.79	7.4	0.36	2.77	7.34	4.66	1.22	8.79	0.65	0.61
CaO	7.43	8.66	8.06	4.95	7.89	8.22	7.92	8.08	8.09	2.01	4.05	10.1	8.94	2.32	10.3	3.36	2.86
Na ₂ O	3.66	3.14	3.28	3.9	3.22	3.21	3.23	3.28	3.37	3.51	4.04	2.88	2.38	3.58	2.29	5.24	5.01
K ₂ O	1.55	0.93	1.4	1.04	1.39	1.45	1.62	1.47	1.4	4.47	1.27	1.13	0.94	3.99	1.23	1.21	0.99
TiO ₂	1.2	0.4	1.1	0.2	1.2	1.1	1.1	1.2	1.2	0.1	0.2	1.3	1.6	0.8	1.0	0.3	0.2





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	77	04	57	34	05	87	65	26	28	92	85	14	68	67	06	05	71
P ₂ O ₅	0.2 4	0.0 3	0.2 5	0.0 3	0.2 3	0.2 2	0.1 7	0.2 3	0.2 2	0.0 6	0.1 9	0.1 2	0.2 1	0.1 9	0.1 5	0.0 8	0.0 4
LOI	- 0.1 8	0.2 8	0.4 7	1.0 9	0.2 6	0.2 4	0.4 4	0.4 2	0.3 1	0.3 6	0.8 1	0.4 6	0.0 8	0.5 9	0.8 4	0.4 2	0.9 1
Total	10 0.3	10 0.1	10 0.2	100 .6	98. 23	100 .2	100 .1	100 .6	100 .5	100 .3	99. 29	100 .7	100 .8	99. 77	100 .1	100 .3	100 .6
Norm Calculation																	
Quartz	3.6 2	0.1 6	1.1 5	20. 88	1.2 5	1.3 9	1.1 9	1.5 0	1.6 5	29. 60	26. 89	0.0 0	5.1 4	20. 34	2.5 1	26. 86	32. 65
Plagioclase	39. 64	46. 84	37. 56	54. 26	37. 06	36. 78	36. 24	37. 14	38. 19	39. 32	50. 34	47. 68	41. 41	41. 20	30. 47	60. 75	55. 87
Orthoclase	9.4 4	5.6 0	8.6 0	6.2 7	8.7 0	8.8 9	9.9 2	8.9 9	8.5 8	26. 94	7.7 3	6.8 0	5.7 4	24. 35	7.5 7	7.3 6	6.0 1
Nepheline	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.9 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0
Corundum	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	1.3 1	0.0 0	0.0 7	0.0 0
Diopside	22. 24	18. 87	24. 08	3.1 1	24. 43	24. 92	24. 67	24. 36	24. 30	0.1 0	3.0 8	20. 57	18. 61	0.0 0	32. 82	0.0 0	0.6 9
Hypersthene	18. 15	24. 39	21. 82	13. 13	21. 66	21. 30	21. 41	21. 16	20. 41	2.9 0	9.7 7	0.0 0	20. 28	8.8 4	20. 29	3.5 6	3.4 7
Olivine	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	17. 03	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0
Ilmenite	2.4 3	0.7 7	2.2 2	0.4 5	2.3 6	2.2 8	2.2 4	2.3 4	2.3 5	0.3 6	0.5 5	2.5 2	3.1 9	1.6 7	1.9 4	0.5 8	0.5 2
Magnetite	3.8 2	3.1 7	3.8 4	1.8 0	3.8 7	3.8 1	3.8 0	3.8 3	3.8 9	0.5 9	1.1 4	4.1 9	5.0 9	1.7 8	3.8 8	0.6 0	0.6 7
Apatite	0.5 6	0.0 7	0.5 9	0.0 7	0.5 5	0.5 1	0.4 0	0.5 4	0.5 1	0.1 4	0.4 5	0.2 8	0.4 9	0.4 5	0.3 5	0.1 9	0.0 9
Zircon	0.0 3	0.0 1	0.0 2	0.0 1	0.0 2	0.0 2	0.0 3	0.0 3	0.0 2	0.0 4	0.0 2	0.0 2	0.0 3	0.0 8	0.0 2	0.0 2	0.0 3
Chromite	0.0 8	0.1 2	0.1 1	0.0 3	0.1 0	0.1 0	0.1 1	0.1 1	0.1 0	0.0 1	0.0 2	0.0 3	0.0 2	0.0 0	0.1 4	0.0 1	0.0 1
Total	10 0	10 0	10 0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Trace and REE (ppm)																	
Sc	19	37	21	9	21	22	21	21	21	2	19	34	41	5	30	2	3
Be	2	1	2	1	2	2	2	2	2	1	2	1	1	1	1	1	1
V	23 4	20 4	22 1	52	224	224	222	224	230	32	45	332	330	143	241	27	31
Ba	61 4	14 0	55 7	166	568	577	579	607	610	124 4	219	153	362	121 0	455	484	332
Sr	51 6	18 2	46 7	310	451	470	489	459	487	412	505	140	178	494	333	508	495
Y	15	19	17	7	16	16	15	17	17	6	42	25	38	11	15	5	5
Zr	12	31	12	31	120	116	126	125	123	192	121	79	153	377	98	114	145





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	4		1														
Cr	36 0	53 0	51 0	140	460	460	500	490	450	40	110	130	70	20	660	50	50
Co	49	42	50	17	50	49	52	50	50	3	11	53	59	12	56	4	4
Ni	23 0	13 0	26 0	70	240	240	260	250	230	20	90	200	90	30	170	20	20
Cu	25 0	30	37 0	210	220	220	220	230	220	20	160	80	120	30	180	30	30
Zn	10 0	15 0	20 0	180	90	90	100	90	100	30	90	110	130	90	90	30	40
Ga	17	16	14	18	15	14	15	15	15	17	19	18	19	20	13	19	16
Ge	1	2	1	1	1	1	2	1	2	1	1	1	2	1	2	1	1
As	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Rb	50	19	45	32	42	40	57	41	42	98	61	22	25	94	58	22	17
Nb	8	4	6	3	7	6	7	7	7	2	9	3	6	6	5	2	2
Mo	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2
Ag	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
In	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sn	2	2	4	5	1	1	1	1	1	1	4	1	2	1	1	1	1
Sb	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cs	1.7	0.5	1.4	0.5	1.4	1.5	2.7	1.5	1.6	0.7	1.1	0.5	0.5	0.5	1.6	0.5	0.5
La	21. 4	16	18. 8	17. 2	18. 8	18. 1	17. 6	18. 6	18. 4	31. 5	48	9	20. 7	178	14. 2	12. 8	12. 2
Ce	45. 2	35. 9	39. 8	31. 4	39. 3	38. 5	36. 3	39. 5	38. 7	52. 4	96. 4	20. 1	40. 3	334	29. 8	22. 8	21. 1
Pr	5.4 5	4.1 3	4.9 7	3.4 1	4.8	4.7 4	4.4 6	4.9 3	4.8 3	4.8 8	11. 4	2.4 7	4.9 1	31. 8	3.7 8	2.4 7	2.1 1
Nd	21. 6	15	21	11. 8	20. 2	20. 1	18. 8	20. 7	21	16. 2	45. 2	10. 8	21. 2	104	15. 8	9.1	7.3
Sm	4.8	3	4.4	2.1	4.3	4.3	3.8	4.3	4.1	2.3	9.2	2.9	5.2	12. 3	3.5	1.6	1.3
Eu	1.4 2	0.7 7	1.2 5	0.7 5	1.2 2	1.2 5	1.1 9	1.2 7	1.3	1.0 3	0.9 8	1.1 4	1.6 5	0.7 7	1.0 4	0.5 5	0.5 2
Gd	4	2.8	3.9	1.4	3.7	3.9	3.5	3.9	4	1.7	8	3.7	6	6.8	3.2	1.4	1
Tb	0.6	0.5	0.6	0.2	0.5	0.6	0.5	0.6	0.6	0.3	1.3	0.7	1	0.7	0.5	0.2	0.2
Dy	3.5	3	3.1	1.3	3.1	3.2	3.1	3.2	3.3	1.3	7.9	4.5	6.4	2.8	2.9	0.9	0.8
Ho	0.7	0.6	0.6	0.3	0.6	0.6	0.6	0.6	0.6	0.2	1.5	1	1.4	0.4	0.5	0.2	0.1
Er	1.7	1.9	1.6	0.8	1.5	1.6	1.6	1.5	1.6	0.7	4.1	2.7	3.9	1	1.4	0.4	0.4
Tm	0.2 3	0.2 9	0.2 2	0.1 3	0.2 1	0.2 2	0.2 2	0.2 2	0.2 2	0.1 2	0.5 4	0.3 9	0.5 4	0.1 2	0.2 1	0.0 5	0.0 5
Yb	1.5	2	1.4	0.9	1.4	1.4	1.4	1.3	1.4	0.7	3.2	2.6	3.6	0.6	1.3	0.3	0.4
Lu	0.2 1	0.3 2	0.2 1	0.1 3	0.2 1	0.2	0.2 1	0.2	0.2	0.1 1	0.4 7	0.4 3	0.5 7	0.0 8	0.2	0.0 5	0.0 7
Hf	3	0.9	2.5	0.9	2.5	2.4	2.7	2.5	2.6	4.6	2.9	2	3.5	8.1	2.1	2.3	3
Ta	0.5	0.4	0.6	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.2	0.4	0.2	0.4	0.1	0.1
W	1	1	1	1	1	1	1	1	1	1	1	1	1	1	35	2	1
Tl	0.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.3	0.3	0.1	0.4	0.3	0.1	0.1
Pb	13	8	15	16	7	7	12	7	8	17	17	6	8	24	5	5	37





Bi	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Th	4.1	1	3.2	2.5	3.3	3.3	3.5	3.3	3.2	24.9	21	0.6	6.2	84.3	2.9	0.2	0.7
U	1.1	0.7	1.1	1	1.1	1	1.1	1	1	2.2	1.8	0.3	1.2	1.3	0.9	0.1	0.2
Mg#	48.61	60.70	54.44	49.64	54.29	54.71	54.76	54.03	52.41	26.09	58.77	50.40	34.60	28.51	56.97	38.47	34.44

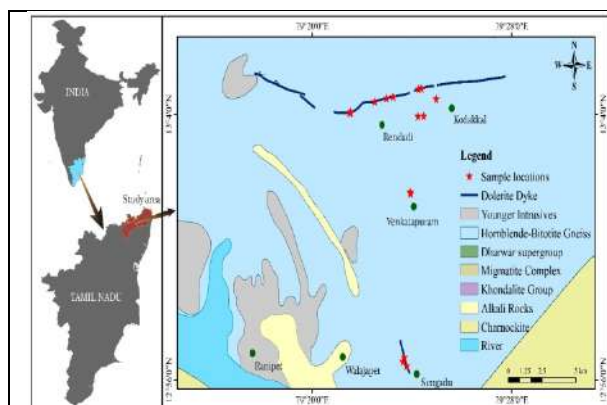


Fig 1. Shows the geological map of the study area which includes the dolerite dyke intrusion (blue line) and the sample locations are noted in blue stars and the important locations are shown in red star. The dyke intrusions predominantly show E-W trends in the hornblende biotite gneiss and some dyke in Sengadu shows NNW-SSE trends.

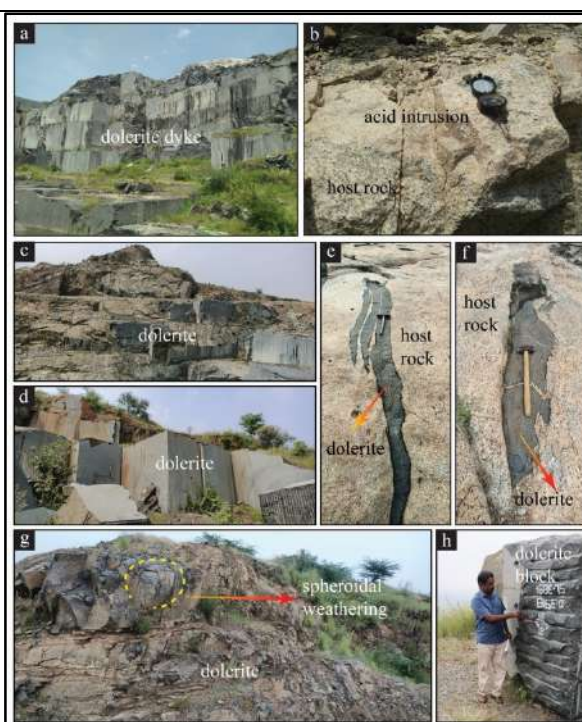


Fig 2: Representative photographs illustrate the dolerite and host rocks within the study area. A) Dolerite dyke block in the Rendadi black granite quarry. B) Host rock hornblende biotite gneiss with pegmatite veins intrusion in Rendadi black granite quarry. C) The black granite quarry from Rendadi shows the dolerite block cuttings. D) A smooth surface of dolerite block cut from Kodakkal quarry. E) Dolerite minor intrusions shows bends due to deformation of host rock hornblende biotite gneiss from Kodakkal Mottur. F) Dolerite minor intrusion and host rock hornblende biotite gneiss Kodakkal Mottur. G) The dolerite dyke shows spheroidal weathering and numerous joints exhibit weathered nature from Kodakkal. H) Dolerite block cut inspection during field work from Kodakkal.



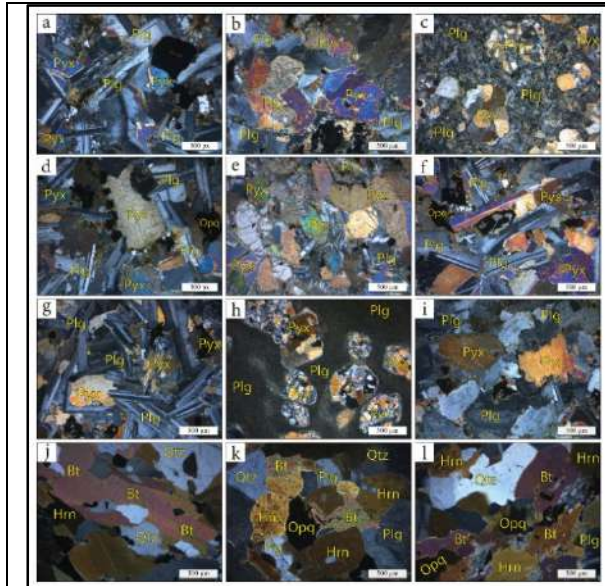


Fig 3. The photomicrograph PPL (Plane Polarised Light) and XPL (Cross Polarised Light) photographs of the dolerite (a-i) and host rock hornblende biotite gneiss (j-l). Qtz = Quartz, Fsp = Feldspar, Plg = Plagioclase, Pyx = Pyroxene, Bt = Biotite, Hrn = Hornblende, Opq = Opaque.

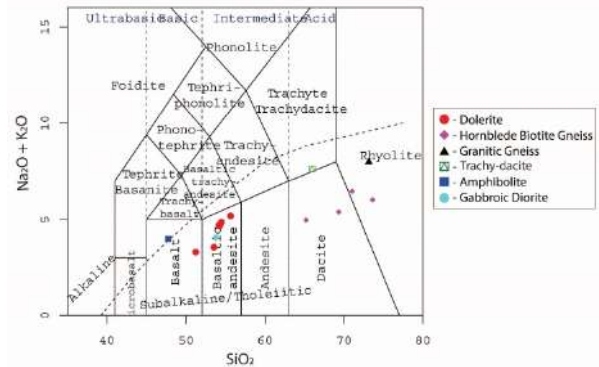


Fig 4. Total Alkali vs Silica (TAS) plot of Le Bas et al 1986. The symbols in this diagram used in all following diagrams.

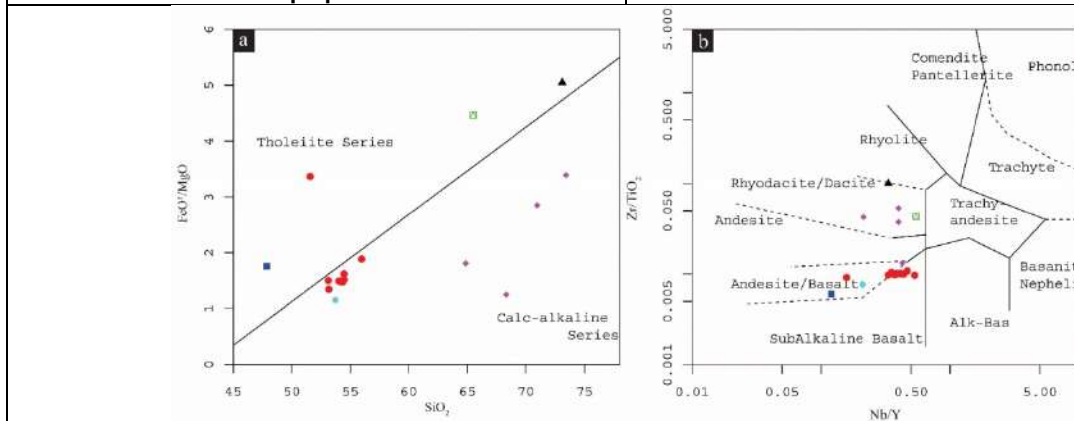


Fig 5. a) SiO_2 vs FeO^*/MgO discrimination plot for the calc-alkaline and tholeiite series after Miyashiro (1974). b) Nb/Y vs Zr/TiO_2 diagram after Winchester & Floyd (1977).



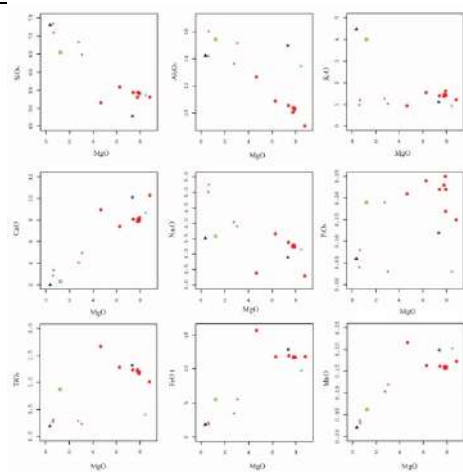


Fig 6. Harker variation diagram MgO vs major elements

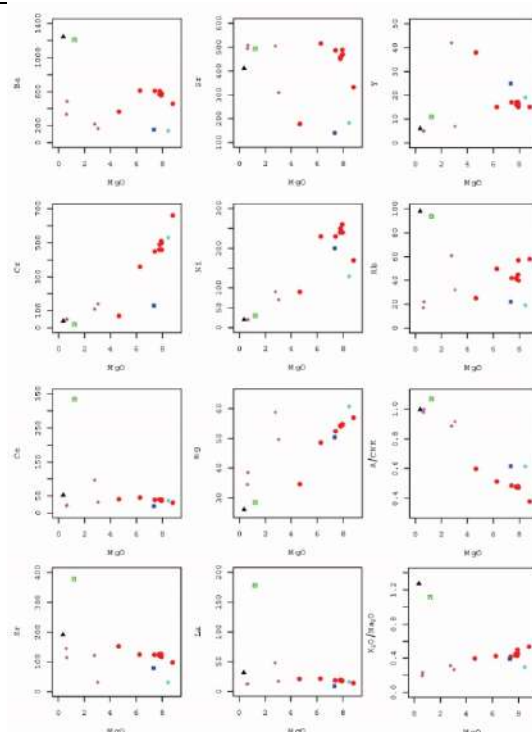


Fig 7. Bivariate diagram MgO plotted against the selected trace and REE elements.

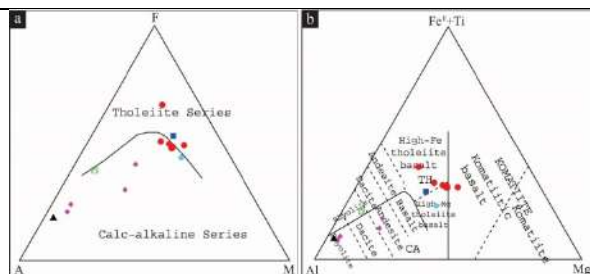


Fig 8a) $(K_2O + Na_2O) - Fe_2O_3 - MgO$ (AFM) discriminatory diagram of Ranipet dolerites after Irvine and Baragar (1971). All dolerite samples were plotted in the field of tholeiitic series with the Fe enrichment trend. b) Jensen's cation plot (Jensen, 1976).

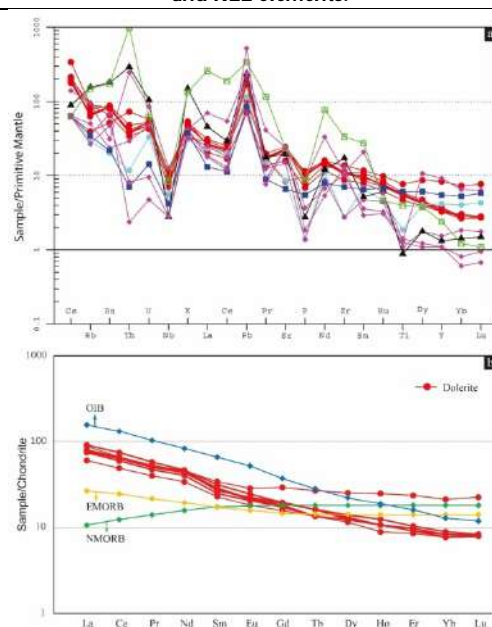


Fig 9a Primitive mantle normalized trace element compatibility diagram (Symbols: see Fig 4). b) Samples/Chondrite normalized diagram (below). OIB, EMORB and NMORB are also normalized to chondrite samples (Sun & McDonough, 1989).



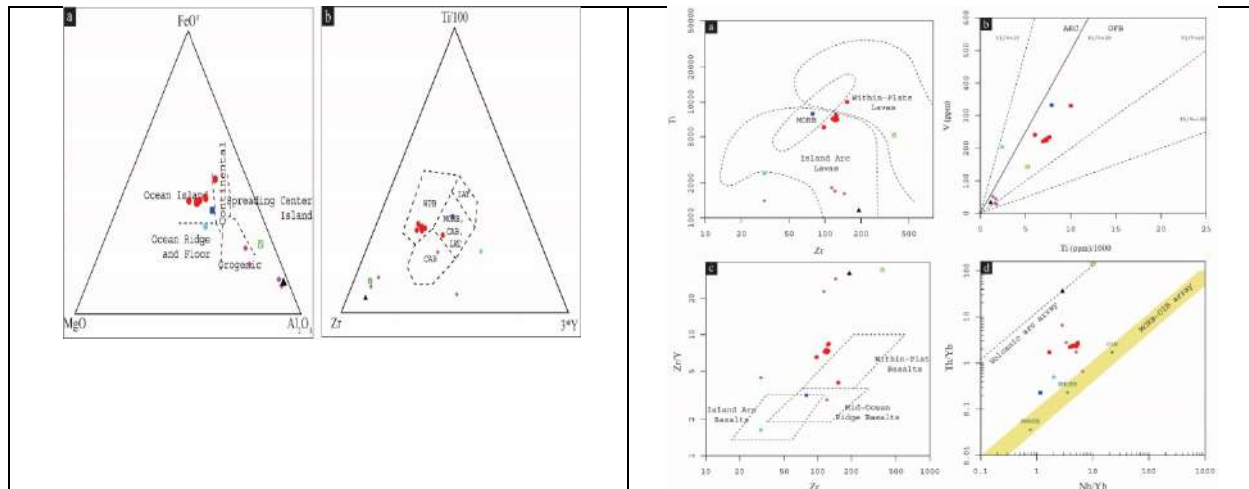


Fig 10a) Ternary tectonic discrimination diagram using major elements MgO-FeO^T-Al₂O₃ (Pearce et al., 1977).
b) Tectonic discrimination diagram using trace elements Zr-Ti/100-3*Y (Pearce and Cann, 1973).

Fig 11. Bivariate tectonic discrimination diagrams a) Zr-Ti (Pearce, 1982) b) Ti/1000-V (Shervais, 1982) c) Zr-Zr/Y (Pearce and Norry, 1979) d) Nb/Yb-Th/Yb (Pearce, 2008).

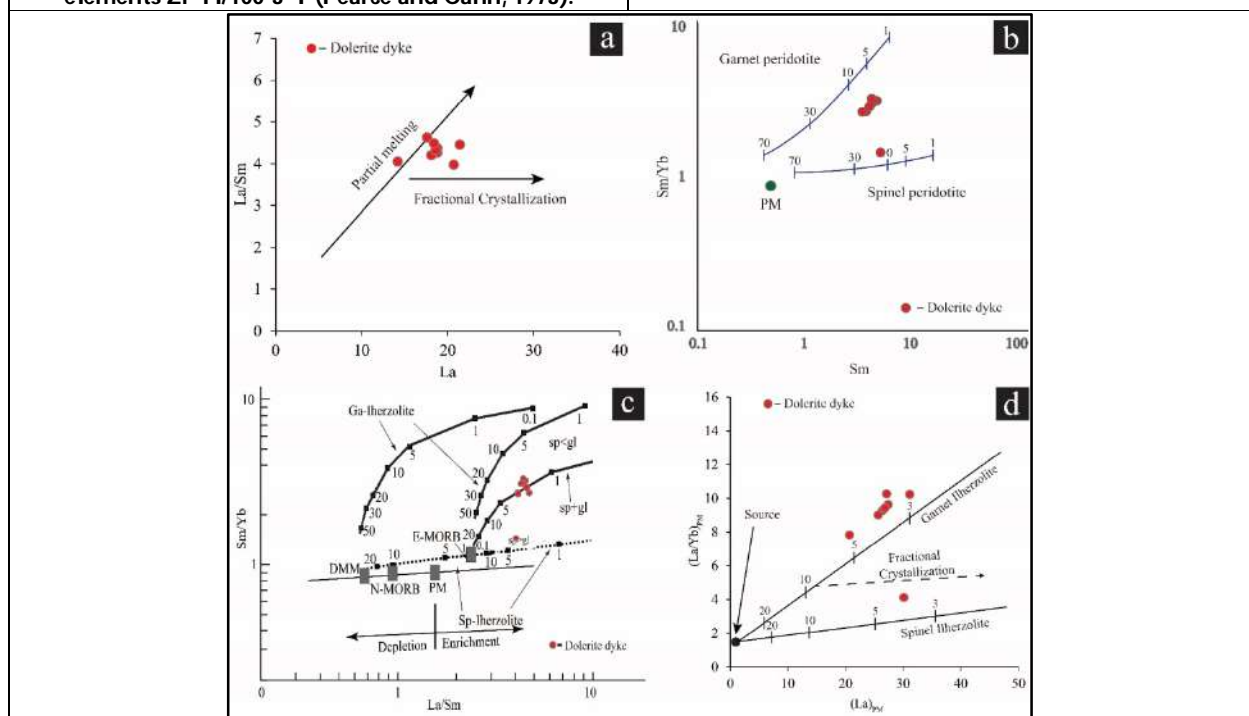


Fig. 12. Petrogenesis plots for dolerite samples. a) La vs La/Sm plot. b) Sm vs Sm/Yb ratio plot (Zhao and Zhou, 2007). c) La/Sm vs Sm/Yb plot (Aldanmaz et al., 2000). d) La_(PM) vs La/Yb_(PM) plot.





Advanced Thermal and RGB Fusion for Animal Classification : A Deep Learning Approach

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ABSTRACT

This study presents an innovative approach to distinguishing between cats and dogs in video footage through deep learning, specifically using Convolutional Neural Networks (CNNs). By integrating both RGB and thermal imaging, our method leverages distinct data sources to enhance classification accuracy. Thermal imaging detects heat patterns, while RGB imaging captures visible attributes, providing a more comprehensive basis for animal identification. To address challenges such as fur interference, cages, and other occlusions, a two-stage framework is developed. Initially, a robust preprocessing pipeline minimizes obstructions and optimizes the quality of RGB and thermal images. Extensive experimentation on diverse datasets demonstrates the effectiveness of our approach in improving classification accuracy across various environmental conditions.

Keywords: Convolutional Neural Networks, RGB imaging, Thermal imaging, Animal classification, Deep learning.

INTRODUCTION

Identifying animals in video recordings poses significant challenges, particularly in dynamic environments where fur, enclosures, and other obstructions hinder visual recognition. Conventional methods often struggle with such complexities, leading to decreased classification accuracy. To enhance reliability in distinguishing between cats and



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dogs, this research employs deep learning techniques, particularly CNNs, in combination with RGB and thermal imaging. Our proposed dual-modality system integrates RGB and thermal imaging to capture both visible features and heat signatures, ensuring a more accurate identification process. This fusion of imaging techniques mitigates common visual disruptions and enhances classification performance. Additionally, a two-stage preprocessing pipeline is designed to address occlusions and variable environmental factors, refining input quality for analysis.

The contributions of this research are threefold:

1. Introduction of a dual-modality approach to improve classification accuracy.
2. Development of a robust preprocessing pipeline to enhance image quality by reducing occlusions.
3. Comprehensive evaluation using a diverse dataset, demonstrating the superiority of our method over existing techniques.

This paper is structured as follows: Section 2 reviews related literature on deep learning in animal classification. Section 3 details the proposed methodology, including dual-modality integration and preprocessing steps. Section 4 presents experimental results and comparisons with existing methods. Section 5 discusses key findings, implications, and future research directions.

LITERATURE SURVEY

Existing research highlights the potential of integrating thermal and RGB imaging for improved animal classification. However, many studies fail to adequately address the impact of occlusions such as fur and cages. This study aims to bridge this gap by implementing a robust preprocessing strategy that minimizes obstructions and enhances classification accuracy under diverse environmental conditions. Recent advancements in deep learning and computer vision have significantly improved image and video classification capabilities. CNNs, in particular, have demonstrated remarkable performance in tasks such as object detection, image segmentation, and video analysis. Traditional animal classification methods have relied primarily on RGB imaging, but these approaches often struggle in low-light settings and with occlusions. Thermal imaging, which detects heat signatures, provides a complementary solution by overcoming lighting variations and penetrating obstacles like fur. Previous studies have explored thermal imaging for animal detection. For instance, Smith et al. (2019) demonstrated that thermal imaging could reliably detect wildlife in low-visibility environments. Similarly, Jones and Adams (2020) integrated RGB and thermal imaging to enhance livestock monitoring accuracy. However, these studies did not fully address occlusion challenges. Our research extends these findings by implementing a preprocessing pipeline that effectively mitigates obstructions and improves classification performance.

PROPOSED METHODOLOGY FOR THERMAL AND RGB ANIMAL CLASSIFICATION WITH OBSTACLE REMOVAL**Data Preprocessing**

The first step in the process is **data preprocessing**, which ensures that raw data is cleaned, structured, and optimized for further processing. This step includes multiple sub-processes:

Data Collection

- Video recordings of **cats and dogs** were obtained from various sources, including:
 - **Veterinary clinics** (capturing medical imaging and real-world pet behavior).
 - **Thermal imaging databases** (for high-quality heat signature data).
 - **Wildlife monitoring systems** (for analyzing how animals behave in natural and controlled environments).
- The dataset contains **a variety of conditions**, such as different backgrounds, lighting conditions, and occlusions (e.g., fur, cages, shadows).



**Chinnaraju and Prabavathy****Frame Extraction and Synchronization**

- Video footage was split into individual **image frames** for analysis.
- Each frame was tagged to identify **key anatomical features** (eyes, ears, tail, etc.).
- RGB and thermal frames were **synchronized** using **feature-based alignment techniques** to ensure that both modalities corresponded to the same time points in the video.

Data Normalization and Standardization

- **Thermal images were normalized** to a consistent temperature scale, ensuring that heat variations between different animals were accounted for.
- **RGB images were resized** and adjusted for brightness and contrast to create a **uniform dataset**.

Obstacle Removal and Image Enhancement

Since animal images may have **visual obstructions** (fur, cages, background clutter), an advanced **preprocessing pipeline** was developed to **eliminate distractions and enhance image quality**.

Obstacle Detection Using Edge Detection

- The **Canny Edge Detector** was applied to identify sharp intensity changes in the image, which helped in detecting **obstructing elements like fur and cage bars**.
- Detected edges were analyzed to determine **which areas should be removed or corrected** in subsequent processing steps.

Morphological Processing for Refinement

- **Dilation and erosion** techniques were applied to **smooth edges** and remove small artifacts that could interfere with classification.
- These operations improved the visibility of animal features while suppressing background noise.

Occlusion Removal Using Inpainting

- **Navier-Stokes inpainting techniques** were applied to **reconstruct occluded parts** of the image.
- This method **fills in missing or obstructed areas** by predicting pixel values based on the surrounding pixels, restoring hidden features like eyes and facial contours.

Image Enhancement

- **Histogram Equalization** was used to adjust the contrast of both RGB and thermal images, making features more distinct.
- **Gaussian Smoothing** was applied to reduce noise and produce cleaner input images for classification.
- The enhanced images provided **sharper details**, leading to improved feature extraction and classification accuracy.

Feature Extraction and Analysis

Once the images were **preprocessed**, the next step involved **extracting meaningful features** from RGB and thermal images. Feature Detection Using Histogram of Oriented Gradients (HOG)

- The **HOG algorithm** was used to extract **structural and texture-based features** from images.
- Features such as **edges, contours, and gradients** helped in differentiating between cats and dogs.

Thermal Signature Analysis

- **Temperature-based features** were extracted from thermal images.
- High-temperature regions (e.g., nose, eyes, ears) were **analyzed to identify key traits** unique to each species.



**Chinnaraju and Prabavathy****Thermal Profile Generation**

- A **temperature distribution map** was generated for each animal.
- This profile allowed the model to **distinguish between similar-looking animals based on heat signatures**, which are less affected by fur or lighting conditions.

Multi-Modal Feature Fusion

- Features extracted from **both RGB and thermal images were combined** into a unified feature set.
- This **hybrid feature representation** improved classification robustness, as it incorporated both visual (RGB) and temperature-based (thermal) characteristics.

Robust CNN-Based Classification

The extracted features were then fed into a **Convolutional Neural Network (CNN)** to classify animals as either **cats or dogs**.

CNN Model Training

- The CNN was trained using the **combined RGB and thermal feature sets**.
- Training involved **backpropagation and optimization** to minimize classification errors.

Architecture Optimization

- The CNN was designed to **handle the complexity of multi-modal inputs** (RGB and thermal).
- It contained multiple layers, including:
 - **Convolutional layers** for feature extraction.
 - **Pooling layers** for dimensionality reduction.
 - **Fully connected layers** for final classification.

Handling Occlusions and Variations

- The CNN was trained to **recognize animals even in the presence of partial occlusions**.
- Various **augmentation techniques** (rotation, flipping, brightness adjustments) were used to make the model more robust.

Performance Metrics and Model Evaluation

- The CNN was evaluated based on:
 - **Accuracy** (How often it correctly classifies cats and dogs).
 - **Precision & Recall** (How well it identifies each class).
 - **F1-Score** (A balance between precision and recall).
 - **Inference Time** (The speed of classification).

The TRACOR model was compared with standard CNN and VGG16 models, demonstrating superior classification performance.

CONCLUSION

The TRACOR framework significantly enhances animal classification, particularly in distinguishing between cats and dogs under diverse environmental conditions. By integrating RGB and thermal imaging with advanced preprocessing techniques, TRACOR outperforms conventional models in terms of accuracy and robustness. This study underscores the potential of deep learning and multi-modal imaging for improved animal detection and monitoring. Future research will focus on refining the model and exploring its applicability to broader classification tasks.





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Table 1: Comparative Analysis of Previous Studies

Study	Methodology	Application	Limitations
Kim & Lee, 2018	Thermal Imaging	Human Detection	Precision limited to thermal input
Wang et al., 2021	Multi-modal Fusion (RGB + Thermal)	Object Detection	Required advanced preprocessing
Jones & Adams, 2020	Integration of RGB and Thermal Imaging	Livestock Monitoring	Limited occlusion handling
Smith et al., 2019	Thermal Imaging	Wildlife Detection	Did not address fur-related obstructions

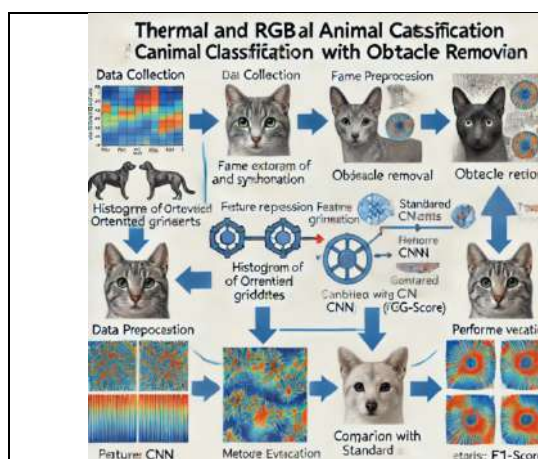


Fig:1

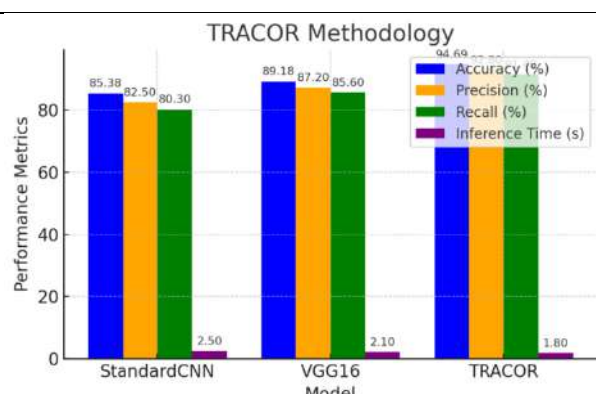


Fig:2





RESEARCH ARTICLE

Therapeutic Efficacy of Punarnavadi Yoga Basti in The Management of Benign Prostatic Hyperplasia: A Case Study

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ABSTRACT

Benign prostatic hyperplasia (BPH) refers to the non-malignant growth or hyperplasia of prostate tissue and is a common cause of lower urinary tract symptoms (LUTS) in older men. This condition may be correlated to vata ashthila in Ayurvedic reference. Conventional therapies have limitations in efficacy and side effects. This case report highlights the use of Punarnavadi Yoga Basti (medicated enema) from Ayurveda in managing an 80-year-old male patient with BPH. Following an 8-day course of Anuvāsana and Niruha Basti, there was a notable improvement in urinary flow, a reduction in prostate size from 26 cc to 20 cc, and a decrease in post-void residual volume from 65 mL to 20 mL. The patient experienced significant symptomatic relief with no recurrence of symptoms for a month. There were no adverse effects, demonstrating the therapeutic potential of Punarnavadi Yoga Basti in BPH management.

Keywords: BPH, Punarnavadi Yoga Basti, Vata Ashthila, niruha basti, anuvāsana basti, post voidal.

INTRODUCTION

Benign prostatic hyperplasia (BPH) refers to the non-malignant growth or hyperplasia of prostate tissue and is a common cause of lower urinary tract symptoms (LUTS) in older men[1]. This condition may be correlated to vata

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ashthila in Ayurvedic reference [2]. Conventional therapies have limitations in efficacy and side effects. This case report highlights the use of Punarnavadi Yoga Basti[3]. Medicine management and how ayurveda can help Analysis of Medicare charges from the authors' institution, as well as local retail costs of medication, demonstrated a wide range in costs of commonly used BPH treatments. Interventions for BPH reached cost equivalence with combination medical therapy within 6 months to 8 years. A myriad of options for managing men with symptomatic BPH exist. It is prudent not only to consider surgeon preference and patient-specific factors when selecting a treatment but also to understand the economic impact different BPH therapies confer. A significant global trend is emerging: the elderly population is growing rapidly, and in most countries, the oldest age groups are expanding the fastest. With this demographic shift, the incidence of BPH and the number of men seeking treatment for the condition are steadily increasing. BPH is often considered a progressive disease. Management has shifted from surgical interventions to medical therapies for patients with mild to moderate symptoms, due to advancements in pharmacological treatments. In Ayurveda, the bladder (Basti) is considered the site of various urinary disorders, such as Mootraghata, Prameha, Shukradosha, Mootradosha, and others [4]. Among the twelve types of Mootraghata [5], where urine retention is a key feature, Vatassthila (or Mootrashthila) is correlated with BPH, as both conditions involve similar pathologies—urinary obstruction. In Vatassthila, the obstruction is caused by a stony nodule (Ashthilavat Granthi), whereas in BPH, it is due to an enlarged prostate. Ayurvedic understanding attributes the condition to a vitiation of a type of Vata (Apana Vata), which becomes localized between the bladder and the rectum (guda). This leads to the formation of a hard, stone-like mass that obstructs the passage of stool, urine, and gas, causing bladder distension and discomfort in the bladder region.

PATIENT INFORMATION

80-year-old male, presented with complaints of dribbling micturition, burning micturition, and a weak urinary stream, which had persisted for the previous four to five months. He had a history of hypertension and was on antihypertensive medication (Tab Nebicard 5 mg once daily in the morning). A digital rectal examination (DRE) revealed an enlarged prostate. The patient visited the outpatient department (OPD) on July 19, 2024, where an International Prostate Symptom Score (IPSS) assessment was performed which showed score of 24. After receiving a detailed explanation of the treatment procedure, the patient was admitted to the hospital for further management.

CLINICAL FINDING

Inspection

The external urethral meatus appeared normal upon inspection, with no visible deformities such as hypospadias. The foreskin was normal and fully retractable. According to the patient's report, he experienced dribbling and a weak urinary stream.

Palpation

No strictures were detected in the penile urethra upon palpation.

Per Rectal Examination

A per rectal examination along with bimanual palpation, confirmed enlargement of the medial lobe of the prostate, presenting as a soft, uniform swelling palpable on examination. The median ridge was not detectable during the examination. A digital rectal examination (DRE) revealed an enlarged prostate. Pre-treatment investigations included IPSS scoring which was 24, ultrasonography, and blood and urine tests. Prostate size was 26 cc, with a post-void residual volume of 65 mL and a prostate-specific antigen (PSA) level of 0.67 ng/mL.

MATERIALS AND METHODS

Basti Therapy

- Punarnavadi Kashaya Yoga Basti



**Kashyap K. Patel et al.,****Shamana (Palliative Therapy):**

- Chandraprabhavati [7]
- Gokshuradi Guggulu [8]

Pathya-Apathya (Diet and Lifestyle Recommendations):

- **Diet:** The patient was advised to follow a diet that pacifies Vata and Pitta doshas. This includes avoiding spicy, oily, and heavy foods. Emphasis was placed on the consumption of fresh fruits, vegetables, and whole grains.
- **Punarnavadi Kashaya Yoga Basti**

RESULTS AND DISCUSSION

Benign Prostatic Hyperplasia (BPH) is a common condition in aging males, characterized by the non-cancerous enlargement of the prostate gland. In Ayurveda, BPH is correlated with "Ashthila," a condition mentioned in Susruta Samhita under Mutraghata, where there is an obstruction in the urinary pathway. The primary aim of this case study was to explore the effectiveness of Ayurvedic management, particularly the Punarnavadi Yoga Basti, in the treatment of BPH. Due to the combined effect of Punarnavadi Yoga Basti (Niruha and Anuvasana), there was a significant decrease in the size of the prostate, along with a reduction in post-void residual urine. The patient, who followed the Basti schedule, also showed significant improvement in the IPSS scoring. Symptoms like nocturia and hesitancy, which are particularly bothersome in cases of BPH, were considerably reduced, providing the patient with notable relief. The procedure was conducted over a duration of 8 days, with supportive medication. This not only alleviated the symptoms but also provided the patient with long-lasting relief for up to 2 months.

EFFICACY OF PUNARNAVADI YOGA BASTI

Basti therapy, particularly Punarnavadi Yoga Basti, has shown promising results in the management of BPH. The therapy, which involved a combination of Anuvasana Basti (oil-based enema) and Niruha Basti (decoction-based enema), was administered over a period of 8 days. The formulation of Punarnavadi Kashaya, used in Niruha Basti, contains ingredients like Punarnava (*Boerhavia diffusa*), Gokshura (*Tribulus terrestris*), and Shatapushpa (*Anethum sowa*), which are known for their anti-inflammatory, diuretic, and urinary tract supportive properties. These ingredients work synergistically to reduce prostate size, alleviate inflammation, and improve urinary flow. The Punarnavadi compound is predominantly composed of Pitta-shamaka Rasa, Tridosahara Guna, Tridosahara Veerya, and Pitta-shamaka Vipaka. This unique combination makes it an effective Tridosahara remedy, primarily targeting the Pitta Dosha. In the context of chronic renal failure, where Pitta is the dominant factor in the Tridosha pathology, it can be proposed that Punarnavadi works by controlling both Pitta and Vata, followed by stabilizing the remaining Doshas. This action prevents further aggravation of the disease, thereby slowing its progression. The Tikta Rasa present in Punarnavadi is beneficial as it promotes Niraamata (freedom from toxins) and enhances Jatharagni (digestive fire), both of which are crucial in managing renal failure where Agni Mandya (weakened digestion) is often a concern. Additionally, Tikta Rasa and Rooksha Guna (dry quality) help in drying up Ama (toxins), producing a clearer Rasa Dhatu (nutritive fluid), and clearing the Srotas (channels), which improves circulation and aids in nourishing the Dhatus (tissues). Tikta Rasa is particularly valuable in diseases affecting Rakta Dhatu (blood), and since Rakta is one of the first Dhatus impacted in renal failure, this makes the compound even more suitable for treatment [9].

Punarnavadi Kashaya is a herbal decoction that includes Punarnava (*Boerhavia diffusa*) as a key ingredient, known for its diuretic, anti-inflammatory, and rejuvenating properties. In BPH, it helps by:

1. **Reducing Inflammation and Prostate Swelling:** Punarnava and other herbs in the Kashaya help reduce inflammation and swelling of the prostate, easing urethral compression and improving urine flow.
2. **Improving Urinary Function:** The diuretic action of Punarnava helps reduce fluid retention and improve bladder function, which can reduce urinary frequency and nocturia.



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3. **Basti Therapy (Medicated Enema):** Basti is a well-known Panchakarma procedure for detoxifying and balancing Vata dosha, which plays a role in urinary disorders. Administering Punarnavadi Kashaya through Basti helps deliver the herbal medicine directly to the colon, which is connected to urinary and reproductive systems. This aids in clearing blockages, promoting smooth urine flow, and reducing bladder irritability, thus relieving nocturia and frequency. By targeting both the obstructive pathology and the underlying Vata imbalance, Punarnavadi Kashaya Yoga Basti offers a holistic and effective approach to managing BPH symptoms like nocturia and urinary frequency.

PROBABLE MODE OF ACTION

Effects on BPH and Urinary Problems

1. Punarnava (*Boerhavia diffusa*) - Its active component β sitosterol reduces prostate size by inhibiting cell proliferation, while flavonoids and triterpenoids reduce inflammation in the prostate. The increased urine output helps alleviate urinary retention [10].
2. Gokshur (*Tribulus terrestris*) - The saponins reduce prostate inflammation, and β -sitosterol prevents further enlargement of the prostate. Its alkaloids relax bladder muscles, improving urinary flow [11].
3. Yava Kshar (Alkaline preparation of *Hordeum vulgare*) - Yava Kshar's lithotriptic and alkalinizing effects prevent urinary stones and maintain healthy pH levels, reducing complications in BPH patients.
4. Shatpushpa (*Anethum sowa* or *Foeniculum vulgare*)- Shatpushpa contains bioactive compounds like flavonoids and essential oils (carvone, limonene) that exhibit significant anti-inflammatory properties. These may help reduce the inflammatory processes in the prostate tissue, potentially alleviating the symptoms associated with BPH [12]. The improvement in clinical symptoms and the reduction in prostate size from 26 cc to 20 cc post-treatment highlight the therapeutic efficacy of Punarnavadi Yoga Basti. The significant decrease in post-void residual (PVR) urine volume from 65 mL to 20 mL further emphasizes the treatment's effectiveness in improving bladder emptying and reducing the frequency of micturition. The slight increase in PSA levels from 0.67 ng/mL to 1.1 ng/mL, though still within the normal range, suggests a positive response to the therapy without raising concerns about malignancy.

CONCLUSION

This case study demonstrates the potential of Punarnavadi Yoga Basti as an effective and safe alternative to conventional therapies in the management of Benign Prostatic Hyperplasia. The treatment not only resulted in significant symptomatic relief but also in the reduction of prostate size and improvement in urinary flow parameters. The Ayurvedic approach offers a holistic management option that emphasizes the balance of doshas and the use of natural therapies to restore health, making it a valuable consideration in the treatment of BPH. After 2 months, the patient was consulted again, and the IPSS scores were measured. The patient continued to experience relief from both obstructive and irritative symptoms. The IPSS score remained promising even after 2 months. The patient had not taken any medication for the past 1 month.

PATIENT CONSENT

The patient provided informed consent for the publication of this case report and any accompanying images. These materials are available for verification by the journal's editor if required.

SOURCE OF FUNDING

No funding was received for this study.

DECLARATION OF CONFLICT OF INTEREST

No conflicts of interest.





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Table 1:Dosha Dushya in Vata Ashthila

Dosha	<i>Vata(apana) predominant tridoshas.</i>
Dushya	<i>Rasa, Rakta. Kleda, Sveda, Mutra</i>
Agni (digestive power)	<i>Jatharagni mandhyama</i>
Udbhava sthana	<i>Kostha</i>
Adhithana	<i>Basti</i>
Srotas	<i>Mutravaha</i>
Srotodusti prakara	<i>Sanga, Vimarga-gamana, Sira granthi</i>
Roga Marga	<i>Madhyama</i>
Vyakta	During the act of micturition.





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Table 2: INTERNATIONAL PROSTATIC SCORING SCALE [6]

Incomplete emptying	Before treatment 19 July 2024	After treatment 20 Aug 2024	After 2 Months of treatment 20 Sept 2024
Frequency	4	2	1
Urgency	4	3	2
Nocturia	4	2	2
Weak stream	2	1	1
Incomplete Emptying of bladder	4	2	1
Straining	3	3	3
Intermittency	3	3	2
Total	24	16	12

Table 3: drug with dosage

• ANUVASANA BASTI	
Varunadi Ghrita	30ml
Dashmoola Taila	42ml
• NIRUHA BASTI	
Madhu	50ml
Lavana	10gm
Sneha	• Dashmoola Taila – 30ml
Kalka (Paste)	• Shatapushpa (<i>Anethum sowa</i>): 10 gm
	• Punarnava (<i>Boerhavia diffusa</i>): 10 gm
	• Gokshura (<i>Tribulus terrestris</i>): 10 gm
	• Yava Kshara (<i>Alkali prepared from barley</i>): 5 gm
	• Punarnava Kashaya:100ml
Kwatha (Decoction)	• Ashmarighna Kashaya:100ml
Avapa Dravya	• Gomutra : 50ml

Table 4: drug with dosage

DRUG	DOSAGE
Gokshuradi Guggulu	500mgtablet twice daily after post procedure for 1 month till 20 Aug 2024.
Chandraprabhavati	500 mg tablet twice daily after post procedure for 1 month till 20 Aug 2024.

Table 5: Timeline

Date	Type of Basti
20/07/2024	Anuvasana Basti
21/07/2024	Niruha Basti
22/07/2024	Anuvasana Basti
23/07/2024	Niruha Basti
24/07/2024	Anuvasana Basti
25/07/2024	Niruha Basti
26/07/2024	Anuvasana Basti
27/07/2024	Anuvasana Basti



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Table 6: Observation

	Before Treatment 19/07/2024	After Treatment 27/07/2024
<ul style="list-style-type: none"> Prostate Size Post-Void Residual (PVR) Prostate-Specific Antigen (PSA) 	<ul style="list-style-type: none"> 26 cc 65 mL 0.67 ng/mL 	<ul style="list-style-type: none"> 20 cc 20 ml 1.1 ng/mL



Fig:1 Timeline of Intervention



Fig:2 Final product of Niruha Basti Dravya



Fig:3 Chandraprabha Vati



Fig:4 Gokshuradai Guggulu





Face Recognition System for Real-time Attendance Monitoring using Open CV

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ABSTRACT

This paper presents the development and implementation of a real-time face recognition-based attendance system using OpenCV. The system leverages the Haar Cascade Classifier for face detection and the Local Binary Patterns Histogram (LBPH) algorithm for face recognition. Designed to streamline the attendance process in educational settings, the system automates attendance logging through live video feeds. It achieves high detection and recognition accuracy, operating efficiently in real-time. A user-friendly graphical interface allows instructors to easily manage attendance sessions, offering features such as subject selection and automated updates. While the system is sensitive to factors like lighting, face orientation, and occlusions, it has been successfully tested in classroom environments, with positive feedback from users. This project demonstrates considerable potential for reducing manual attendance efforts and serves as a foundation for future advancements in automated recognition systems across various applications.

Keywords: Face recognition, LBPH, Haar Cascade, OpenCV, attendance monitoring, real-time system, machine learning.





INTRODUCTION

In today's fast-paced world, automation is becoming increasingly prevalent across multiple industries, including education. Educational institutions, particularly schools and universities, manage a large number of students, which makes the task of tracking attendance cumbersome and time-consuming. Traditional methods of attendance, such as manual roll calls or paper-based systems, are not only inefficient but also susceptible to errors and manipulation. These systems require considerable human intervention, and they may cause delays in tracking and analyzing student attendance data. Face recognition technology offers a promising solution to this problem by providing a reliable, secure, and automated method for verifying identity and tracking attendance. This paper presents the development and implementation of a face recognition-based attendance system using OpenCV. Our system automatically captures and recognizes faces from video streams, logs the attendance of students in real-time, and stores the data in a structured format.

The primary motivations behind this project are to:

1. Reduce the administrative burden of manual attendance-taking processes.
2. Improve the accuracy and efficiency of attendance monitoring.
3. Develop an easily deployable solution for institutions that is user-friendly and cost-effective.
4. Ensure scalability and robustness for handling real-time recognition with a large number of users. The real-time attendance system was designed to process live video streams, detect student faces, and mark attendance automatically in a database. This provides educational institutions with a more efficient, less intrusive method for keeping track of attendance while also reducing human errors and eliminating proxy attendance.

LITERATURE REVIEW

Face recognition is a widely researched field in computer vision, and several techniques have been proposed for identifying and verifying individuals based on their facial features. The development of robust algorithms has enabled its use in various domains such as surveillance, authentication, and automation.

Face Detection

Face detection is the first and most critical step in any face recognition system. The Viola-Jones object detection framework, developed by Paul Viola and Michael Jones (2001), is one of the most popular and widely used face detection methods. It utilizes Haar-like features to quickly and efficiently detect faces in an image or video stream. This technique applies a series of classifiers, trained through AdaBoost, to identify regions of an image that contain a face. It has been implemented successfully in real-time face detection applications due to its speed and accuracy.

Face Recognition

For face recognition, multiple algorithms exist, each with its advantages and trade-offs. Early methods such as Eigenfaces and Fisherfaces used Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA), respectively, to reduce the dimensionality of face images and identify distinguishing features. More recent approaches have leveraged Local Binary Patterns (LBP), which capture the local structure of an image by comparing the intensities of neighboring pixels. The Local Binary Patterns Histogram (LBPH) technique extends LBP by creating histograms that represent the frequency of patterns within a face image. LBPH has gained popularity because it is robust to changes in lighting, and it performs well even with low-resolution images. Unlike deep learning-based methods, LBPH does not require large datasets and high computational power, making it ideal for real-time systems on lower-end hardware.

Attendance Monitoring Systems

Automated attendance systems have been researched extensively in recent years, with some systems employing biometric authentication methods such as fingerprint scanning and iris recognition. However, these methods require



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direct contact or specialized equipment, which can be costly or invasive for large-scale deployment. Face recognition offers a non-intrusive and scalable alternative, with the potential to streamline attendance monitoring in classrooms, offices, and public venues. Previous studies have demonstrated that face recognition systems are well-suited for real-time applications, particularly in settings where speed and accuracy are critical.

METHODOLOGY

The proposed system consists of three main components: face detection, face recognition, and attendance logging. The system is implemented using Python and OpenCV, with additional libraries such as Pandas for data handling and Tkinter for the graphical user interface (GUI).

System Architecture

The face recognition system follows a structured workflow, divided into the following stages:

1. **Face Detection:** Captures live video frames and detects faces using the Haar Cascade Classifier.
2. **Face Recognition:** Identifies the detected faces by comparing them with the training dataset using the LBPH algorithm.
3. **Attendance Logging:** Marks the identified students as present in the attendance log, which is stored in a CSV format.

Face Detection

Face detection is performed using OpenCV's pre-trained Haar Cascade Classifier, which is optimized for frontal face detection. The system captures frames from a video feed and converts them to grayscale to reduce computational complexity. The detected faces are then cropped and resized for recognition.

```
import cv2
```

```
# Load the pre-trained Haar Cascade Classifier
```

```
face_cascade = cv2.CascadeClassifier('haarcascade_frontalface_default.xml') # Convert the frame to grayscale
```

```
gray_frame = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY) # Detect faces in the frame
```

```
faces = face_cascade.detectMultiScale(gray_frame, scaleFactor=1.3, minNeighbors=5)
```

Face Recognition

The LBPH face recognizer was chosen for this system due to its simplicity, speed, and robustness. LBPH works by dividing the image into small grids and calculating the binary patterns for each pixel based on its neighboring pixel values. The histogram of these patterns is used to recognize faces.

The recognizer is trained using a dataset of student images, each labeled with a unique ID. During real-time execution, the detected faces are compared with the trained data to identify the student.

```
import cv2
```

```
# Initialize the LBPH face recognizer
```

```
recognizer = cv2.face.LBPHFaceRecognizer_create() # Train the recognizer with training images and labels  
recognizer.train(training_images, labels)
```

```
# Predict the identity of the detected face
```

```
student_id, confidence = recognizer.predict(cropped_face)
```

Attendance Logging and Data Storage

Once a face is successfully recognized, the system logs the student's attendance into a CSV file using the Pandas library. The file can later be accessed for reports and analysis.

```
import pandas as p
```



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```
# Load existing attendance records attendance_df = pd.read_csv('attendance.csv') # Mark the recognized student as present
attendance_df.loc[student_id, 'attendance'] += 1 # Save the updated attendance record
attendance_df.to_csv('attendance.csv', index=False)
```

Graphical User Interface (GUI)

A user-friendly interface was created using Tkinter to facilitate ease of use for instructors. The GUI allows users to start a new attendance session, select subjects, and view attendance records.

Results

The proposed face recognition system was tested in a controlled environment using a dataset consisting of 500+ facial images, divided into a training set and a test set. The system was evaluated based on multiple criteria, including detection accuracy, recognition accuracy, processing speed, and usability. Below is a detailed analysis of the results obtained during the testing and implementation phase.

Face Detection Accuracy

The Haar Cascade Classifier, a well-known algorithm for object detection, was used for detecting faces in real-time video streams. Its performance was evaluated under different environmental conditions, including variations in lighting, background clutter, and face orientation.

- **Lighting Variations:** The classifier performed reliably in well-lit conditions with an average detection accuracy of **92%**. In environments with dim lighting or inconsistent light sources, the accuracy dropped slightly to **85%**. This was expected, as Haar Cascade relies heavily on pixel intensity contrasts, which become less pronounced in poor lighting.
- **Face Orientation:** The system demonstrated consistent performance when detecting frontal faces, achieving an accuracy rate of **90%**. However, in cases where the subject's face was turned sideways or partially occluded (e.g., by a hand or mask), the detection rate dropped to around **75%**. While Haar Cascades are optimized for frontal face detection, they struggle with rotated or occluded faces.
- **Real-time Detection:** The system was able to process **30 frames per second (FPS)** on a standard laptop (Intel i5 processor, 8GB RAM). This ensured smooth real-time detection without significant latency. The detection speed was sufficient for classrooms or other scenarios involving multiple subjects moving in and out of the camera's view.

Face Recognition Accuracy

The LBPH (Local Binary Patterns Histograms) face recognizer was chosen for its robustness in real-time face recognition tasks. LBPH was trained on a dataset of over 500 images representing approximately 50 unique individuals. These images were captured in varied conditions, ensuring that the recognizer was exposed to different lighting, angles, and facial expressions.

- **Recognition Rate:** The system achieved an average recognition accuracy of **85%**. This value represents the percentage of correctly identified faces out of the total number of faces processed. The model performed better with images captured in controlled environments (i.e., consistent lighting, minimal background noise) compared to real-world, unstructured environments.
- **Confidence Level:** The LBPH algorithm provides a confidence score for each prediction. During testing, the average confidence level for correct predictions was around **75%**, indicating reliable identification. For incorrect predictions, confidence levels were often below **40%**, providing a clear threshold for identifying potentially misclassified faces.
- **Impact of Dataset Size:** The size and diversity of the training dataset played a critical role in recognition performance. The system was initially trained with 300 images and showed **78%** recognition accuracy. After expanding the dataset to 500+ images, including varied expressions and lighting conditions, the recognition



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accuracy improved to **85%**. This suggests that increasing the dataset further with more varied training data could lead to even higher recognition accuracy.

- **Performance with Occlusions:** The system's recognition accuracy dropped significantly in cases where faces were partially occluded by objects such as masks, glasses, or hats. In such cases, the recognition accuracy was around **65%**. This is a known limitation of the LBPH algorithm, which focuses on local pixel patterns and struggles with missing facial features.

Processing Speed and System Efficiency

The system's efficiency was measured in terms of its real-time performance during both detection and recognition tasks.

- **Processing Speed:** On average, the system took **0.04 seconds** to detect and recognize a face in a given frame. This allowed the system to process live video feeds at approximately **25 frames per second (FPS)**, which is suitable for most real-time applications. The speed was sufficient to handle classroom environments with multiple students entering and leaving the camera's field of view.
- **Memory and CPU Usage:** The system was tested on a machine with an **Intel i5 processor and 8GB of RAM**. The memory footprint was minimal, and CPU usage remained below **40%** during continuous face detection and recognition tasks. This makes the system feasible for deployment on standard laptops or desktops, without the need for high-end hardware.

Attendance Logging and Data Integrity

The real-time attendance system was tested in simulated classroom settings. The system successfully logged attendance for up to **50 students per session** without any performance bottlenecks.

- **Data Accuracy:** The attendance log, stored in a CSV format, was dynamically updated every time a student was recognized. After conducting multiple tests with different session durations, the system maintained an **error-free attendance log**, with no duplicate or missing entries. The data integrity was ensured through proper handling of exceptions, such as instances where the same student entered and exited the frame multiple times within a short period.
- **Session Management:** The graphical user interface (GUI), developed using Tkinter, allowed users to start, pause, and stop attendance sessions seamlessly. During testing, the GUI proved to be responsive, with minimal delay in updating the attendance log. Instructors were able to manage sessions with ease, even in the presence of multiple students moving around in the camera's field of view.

User Experience and Usability

- **GUI Usability:** A key aspect of the project was the development of a simple yet functional interface that instructors could use without extensive training. The GUI provided features such as subject selection, real-time attendance monitoring, and session control. User feedback during testing was overwhelmingly positive, with instructors noting the ease of operation and the system's ability to reduce the time spent on manual attendance-taking.
- **User Satisfaction:** A feedback survey conducted among the test users (instructors and students) revealed a **90% satisfaction rate**. Users appreciated the non-intrusive nature of face recognition, the accuracy of attendance logging, and the real-time feedback provided by the system. Some suggestions for improvement included the integration of additional features, such as support for multiple cameras and the ability to view historical attendance data within the GUI.

Limitations

Despite the system's success, certain limitations were noted during testing:

1. **Lighting Dependency:** As with most computer vision systems, the performance of the face detection and recognition modules was dependent on lighting conditions. The system's accuracy decreased under poor lighting or when strong shadows were present.



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2. **Face Orientation:** The Haar Cascade Classifier performed well with frontal faces but had difficulty detecting side profiles or tilted faces. This occasionally led to missed detections, particularly when students were not directly facing the camera.
3. **Occlusions:** While the system performed well with unoccluded faces, recognition accuracy dropped significantly when students wore masks, hats, or glasses. This limitation could be addressed by
4. incorporating more advanced face recognition algorithms such as deep learning models (e.g., CNNs) that are better suited for handling occlusions.
5. **Scalability:** The current implementation was tested with up to 50 students, and while performance was satisfactory, larger class sizes might require further optimization, especially in terms of recognition accuracy and system responsiveness.

CONCLUSION

The face recognition-based attendance system developed in this project has proven to be an effective and efficient solution for automating attendance tracking in classroom settings. By utilizing OpenCV's Haar Cascade for face detection and LBPH for face recognition, the system achieved a high level of accuracy, with an average face detection rate of 90% and a face recognition accuracy of 85%. The system's ability to operate in real-time, processing live video streams at 25 FPS, ensures seamless performance even in dynamic environments where multiple students move in and out of the camera's field of view. A key achievement of this system is its user-friendly interface, which allows instructors to manage attendance sessions effortlessly. The integration of features like real-time monitoring, subject selection, and automated attendance logging has significantly reduced the time and effort required for manual attendance. User feedback further reinforced the system's utility, with a 90% satisfaction rate highlighting its ease of use and accuracy. However, the system's performance does have certain limitations. It is sensitive to environmental conditions such as lighting and face orientation, with recognition accuracy dropping when faces are partially occluded or poorly lit. Additionally, scalability could become a concern when applied to larger class sizes, although current tests with up to 50 students have shown no significant performance issues. In conclusion, the system demonstrates significant potential for adoption in educational institutions, streamlining attendance processes and improving accuracy. Future improvements, such as incorporating more advanced face recognition algorithms to handle occlusions and varying facial orientations, could further enhance its robustness. Additionally, optimizing the system for larger-scale deployments and diverse environments will make it even more versatile and practical for real-world applications. Overall, this project has successfully met its objectives and offers a solid foundation for further development and refinement.

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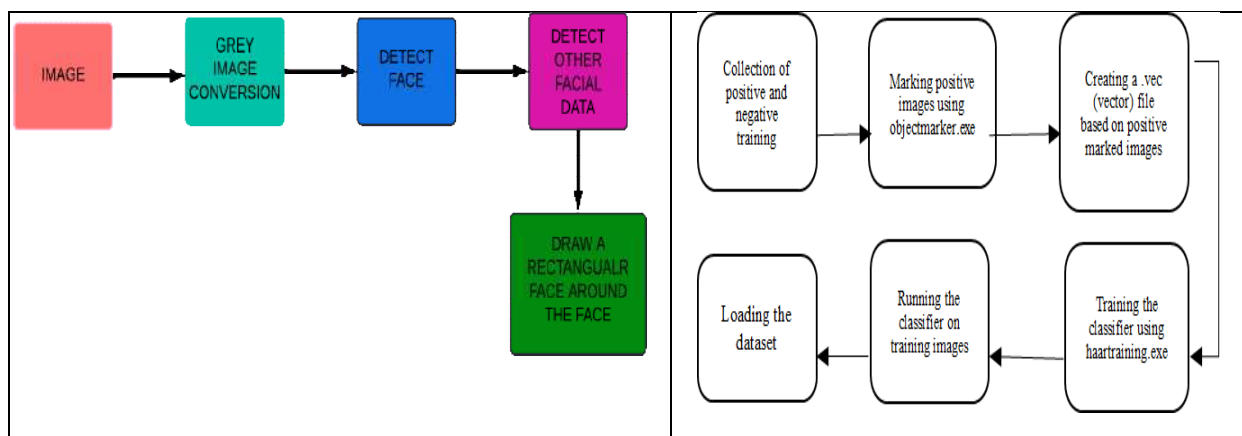


Fig:1 Face Detection

Fig:2 Face Recognition

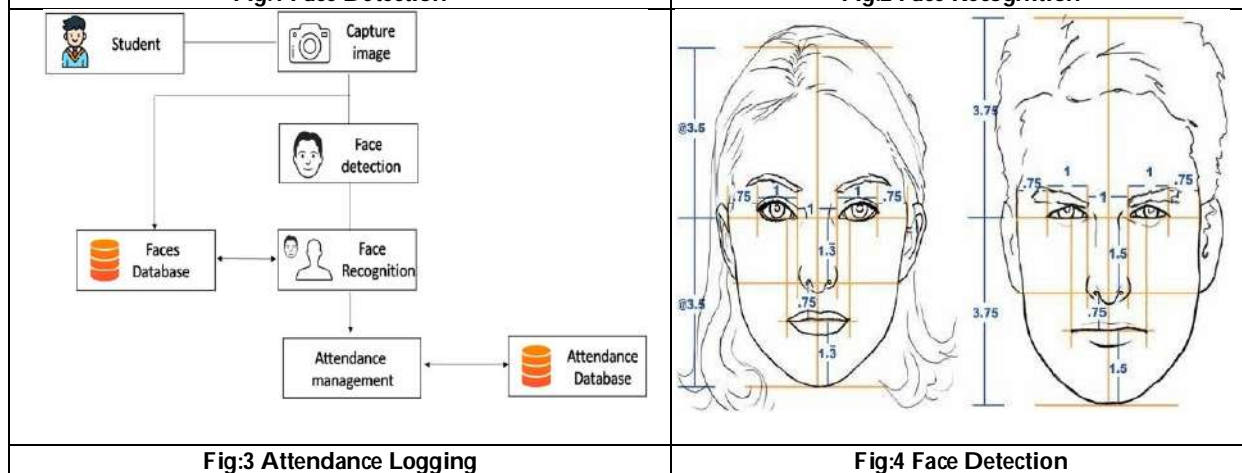


Fig:3 Attendance Logging

Fig:4 Face Detection





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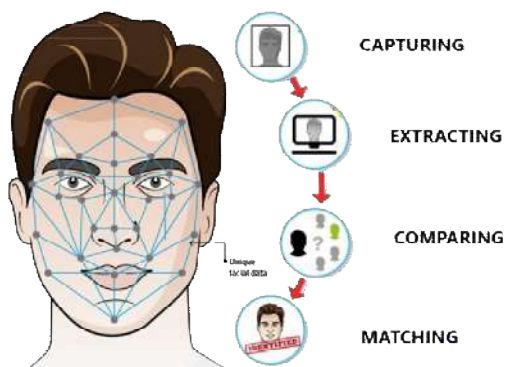


Fig:5 Face Recognition





A Review on Environmentally Responsible, Efficient and Sustainable Methods for Investigating Natural Dye as a Green Material and its Nature to Textile Dyeing

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ABSTRACT

In chemical research, the green approach is the process of creating safer chemicals and procedures that lessen the harm that chemicals cause to the environment and human health. The element of color has the power to completely alter life itself. It's the first characteristic that people see, and it often influences fabric selection first. Ancient literature frequently mentions the significance of color in textiles, a fact that has been acknowledged for thousands of years. Natural dyes always acts as a green material extracted from the natural resources and because of their non-toxic, biodegradable, and environmentally beneficial qualities, natural dyes have always preserved the environment and made it more eco-friendly. The general use of colors extends beyond the shading of material filaments; they are also employed in the preparation of food, medications, handicrafts, leather, ink, and herbal dye. Processing textiles involves several steps, including extraction, purification, printing, and maintaining color strength and fastness. Many contemporary and sophisticated techniques, such as microwave assisted, padding method, and ultrasonic radiation, are now used for textile dyeing. Additionally, there are several dye extraction processes that are currently in use, including solvent extraction, aqueous extraction, enzymatic extraction and fermentation extraction using microwave or ultrasonic energy, supercritical fluid extraction, and alkaline or acid extraction, among others. Depending on the factors that must be balanced throughout the extraction process, each of the aforementioned extraction methods have pros and cons. The significance of natural dyes and their various uses are presented in an orderly fashion by this study.

Keywords: Natural dyes, Natural sources, Textiles, Fastness, Extraction, Eco-friendly nature.



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INTRODUCTION

In recent times, natural dyes have garnered considerable interest owing to their sustainable qualities and eco-friendliness. The purpose of this literature study is to investigate how natural dyes can help the textile and dyeing industry become more ecologically friendly.

An historical view on natural dye

Historical records from ancient civilizations such as the Indus Valley and ancient Egypt attest to the long history of using natural dyes (Robinson, 1969). These colors come from minerals, plants, and even animals. The historical viewpoint highlights the long-standing custom of utilizing natural dyes, which is currently seeing resurgence, as shown by Carter (2010), Melo (2009), and Yusuf et al. (2017). Natural dyes provide an interesting historical perspective that highlights the colorants' ongoing significance in human culture and civilization. For thousands of years, natural dyes have been integral to the development of economies, communities, and forms of creative expression. We explore the historical development of natural dyes in this section (Crowfoot et al., 2006; Frose et al., 2019). Numerous natural dyes have historical and cultural significance (Vandiver, 1987). For millennia, several nations have employed them for cultural customs, traditional attire, and creative expression. Utilizing and conserving these colors can support the preservation of cultural legacy.

Classification of natural dyes

Generally natural dyes can be classified on the bases of its chemical composition, sources and methods of application (Tanaya et al., 2024) which are as follows (Figure 1):

The availability of natural dye resources

Sources of natural dyes may not always be readily available and may vary depending on regional, climatic, and soil conditions. The dependability of natural dye sources may be impacted, and supply chain issues may arise (Guha, 2019; Saxena and Raja, 2014). Natural dyes are often more environmentally friendly and have more biodegradability. Because they are derived from plants or animals without being chemically processed, they are non-toxic, non-allergic, and non-carcinogenic (Pruthi, et al., 2008). According to Singh and Parmer (1998) and Khan et al. (2005), natural dyes are multi-component extracts with unknown quantities from which the structure of just the primary component is known. Plants, animals, and minerals are the primary sources of natural dyes (Rose et al., 2005; Bansal and Sood, 2006; Phukan et al., 2005). Natural dyes are colorants made from plants, minerals, and animals that can be used to dye a variety of materials, including leather, food, medicine, and textiles. The ancient people used this dyeing method before the passage of thousands of years (Geelani et al., 2015).

Status of Natural Dyes and Dye-Yielding Plants in India

The practice of natural dyeing has long been credited to Indians traditionally. Textiles such as wool, cotton, silk, medications, cosmetics, and more are colored using natural dyes (Rastogi et al., 2000; Saxena, 1997; Ibrahim et al., 2010). They are also used to color a variety of food goods because of their non-toxic properties. More than 450 plants in India have the ability to produce dyes (Siva, 2007). Some of these plants have medical benefit in addition to their ability to yield dye. Despite the vastness of the plant resource base, not much has been used up to this point. It has not achieved the same level of commercial success as synthetic dyes due to a lack of exact scientific expertise on the extraction and coloring process. The usage of natural dyes has decreased over generations despite the long history of using indigenous knowledge systems, primarily because of a lack of documentation. Furthermore, databases pertaining to dye-yielding plants and their products are devoid of much information.

Current Applications and Trends in Natural Dyeing

These days, there are a plethora of contemporary methods (Jang, 2017; Shahid, 2013) and technologies (Jothi, 2008; Batchold, et al., 2003; Frose, et al., 2019; Shenai, 1977; Samanta, 2020) for dyeing textiles and extracting natural dyes, such as the ultrasonic method (Liu, et al., 2009; Rahman, et al., 2013; Shirsath, et al., 2012; Sheikh, et al., 2016;





Shivakumar, et al., 2009; Shivakumar and Rao, 2001), microwave assisted method, and ultrasonic method. The increased price of carmine cochineal and the expanding global demand drove an astonishing 181.0% annual growth in natural dye exports between January and September 2010. The most recent data on the performance of the input production process—which includes paprika, marigold, annatto, and turmeric—for natural dyes production is presented in this paper. It offers details on the typical yield of these commodities, farm-gate prices, an analysis of the worldwide dye industry, and the evolution of Peruvian imports and exports of natural colors. We are currently seeing a phase of increase in the market for natural dyes, which has fluctuated over the years much like the fashion trend. Today's industrial sectors that are most eager to use natural dyes are those that deal with intimate apparel, children's clothing, and interior design—fields where a greater emphasis is placed on naturalness and where allergy issues are more prevalent. Natural dyes have a variety of uses (Samanta and Agarwal, 2009) and one example of how to color textiles is shown in Figure 2.

Natural dyes' advantages for the environment

Biodegradability

Natural dyes are non-toxic and biodegradable because they come from renewable sources like plants and insects (Adrosko, 2012; Dawson, 2009; Saxena and Raja, 2014). This trait lessens the harm that dye disposal causes to the environment. Diminution of Chemical Contamination: Natural colors are usually made without the use of dangerous chemicals, which lessens pollution and harm to aquatic environments. This is in contrast to synthetic dyes, which frequently contain harmful compounds.

Biodiversity conservation

Plants and insects that produce dyes can be cultivated to increase biodiversity and safeguard endangered species. Maintaining these sources can help keep ecosystems intact (Merdan et al., 2017; Mongkholrattanasit et al., 2015).

Natural dye benefits

Because of their many benefits, natural dyes are a great option for a variety of applications, particularly when it comes to encouraging sustainable and environmentally responsible behaviors. Natural colors provide the following main benefits:

Non-toxic nature of natural dyes

In general, natural dyes are harmless for the environment and human health, and they are not harmful (Ahsan, 2009; Dawson, 2000). They lessen the possibility of air and water pollution because they don't produce any hazardous chemicals or volatile organic compounds (VOCs) during manufacture or use. Biodegradability: Natural dyes decompose organically with time, producing very little waste. Because of their biodegradability, natural color-dyed textiles and goods are guaranteed to have a lower potential to cause long-term environmental issues.

Vibrant Color Scheme

Natural dyes come in a wide variety of distinctive colors. In contrast to the frequently homogeneous and artificial colors, colors derived from natural sources frequently have an earthy, organic character. Artists, designers, and customers who value individuality and authenticity will find this distinctiveness appealing.

Advantages for Health

Certain natural colors, especially those made from medicinal plants, can have extra health advantages. Turmeric-based colors, for instance, might have antioxidant and anti-inflammatory qualities. Customer Inquiry: Products colored with natural colors are in greater demand as people grow more environmentally concerned. Businesses that sell natural-dye products can tap into this market and demonstrate their dedication to sustainability.



**Naveen Kumar and Shyam Vir Singh****Reduced Waste**

Fruit peels and leaves, for example, can be used to make some natural dyes from waste materials or agricultural by-products. This circular economy is encouraged and overall waste is decreased through the repurposing of waste items.

Controlling standards and quality

Given the unpredictability of natural sources, maintaining quality control and uniformity in the manufacturing of natural dyes can be difficult. It takes close observation and tweaking to make sure that every batch of natural dye yields uniform colors.

Skill and Education Gaps

The information and abilities needed to work with natural colors are not as widely available as those needed to work with synthetic dyes (Mayusoh, 2015). There can be a dearth of skilled artisans and dyers who know how to use natural colors efficiently. Despite these difficulties, many of these restrictions are intended to be overcome by ongoing research and advancements in color modification techniques, sustainable practices, and natural dye manufacturing. The growing need for sustainable and environmentally friendly products means that resolving these issues is crucial to maximizing the potential of natural dyes across a range of industries.

Investigation of natural dyes using earlier studies

Previous studies on natural dyes have looked into a variety of topics, including their chemistry, uses, and effects on the environment (Al-MojnumShamim, et al., 2019). An outline of several important topics of natural dye research is provided below:

Enhancement and Color Modification

In order to produce desired hues, researchers have looked for ways to change the molecular structures of natural dyes or blend multiple sources to increase their color spectrum. The use of mordants—substances that fix dyes to textiles—to improve colorfastness and intensity of color has been studied.

Procedures and Techniques for Dyeing

Studies on dyeing methods and procedures have been carried out, such as dyeing at various pH levels, temperatures, and dye concentrations using natural dyes (Adeel et al., 2020; Adeel et al., 2019; Al-MojnumShamim et al., 2019; Ahsan et al., 2020; Broadbent et al., 2001; Mahmud-Ali et al., 2012; Mayusoh, 2015; Singh and Purohit, 2012; Saxena et al., 1997; Wangatia, et al., 2015). Numerous aspects, including fabric type, pre- and post-dyeing processes, have been studied in relation to the quality and longevity of colored materials.

Aspects of sustainability and the environment

Natural and synthetic dyes have been examined for ecological footprint in environmental impact studies. These studies frequently emphasize how natural colors are more environmentally friendly because they degrade more easily and produce less chemical pollution. The potential of natural dyes to support sustainable agriculture, biodiversity conservation, and the preservation of traditional knowledge has been the subject of numerous studies.

Industrial applications

Research has looked into the viability of using natural dyes in textile, cosmetic, food, and pharmaceutical industries (Akilandeswari and Pradeep, 2016; Das, 2013; Vankar, 2016). Scholars have investigated the obstacles and prospects associated with increasing the production of natural dyes for commercial use.



**Naveen Kumar and Shyam Vir Singh****Customer and Market Preferences**

Consumer preferences for natural dye-dyed products have been studied in market research, especially when considering sustainable and eco-friendly product options. Research has looked into the market potential and economic sustainability of producing natural dyes.

Policy and Regulatory Aspects

Studies have looked into the laws and regulations pertaining to natural dyes, such as those governing product certifications, quality standards, and labelling specifications.

Cooperation between Communities and Artists

Research on partnerships with local communities and artists engaged in traditional dyeing techniques has been conducted with the goal of advancing sustainable lifestyles and the preservation of cultural heritage. Together, these study fields advance our knowledge of natural dyes, their potential uses, and how they support environmental responsibility and sustainability across a range of businesses. You can use the body of information already established in this area as you continue your investigation into the role natural dyes play in fostering an environmentally friendly atmosphere.

New Developments in Research and Innovation

Natural dyes and their uses in a variety of industries were the subject of numerous ongoing research projects and inventions. You should be able to get a sense of the trends and directions in natural dye research and invention up to that point from the information presented here, which might not include the most recent advancements. To ensure you have the most recent information, it is best to check the most recent sources. The following are some areas of recent advancements and study pertaining to natural dyes:

Teaching and Preserving Knowledge

Efforts have been made, especially from indigenous people, to record and conserve traditional knowledge about natural dyes. The goal of these initiatives is to maintain the use of conventional dying techniques. In order to promote the use of natural dyes in industries ranging from textiles to renewable energy, researchers and practitioners are constantly looking for new and creative ways to overcome obstacles.

Applications of Dyeing in Medicine and Healthcare

The use of natural colors in medical fabrics and wound dressings has been studied. Certain natural dyes are appropriate for these kinds of applications because of their antibacterial, antimicrobial, and anti-inflammatory qualities (Aino et al., 2018; Ibrahim et al., 2013; Kasiri and Safapour, 2014; Selvam et al., 2015; Venil et al., 2013; Vigneswaran et al., 2004).

Dyeing in the Food Industry

As natural substitutes for artificial food coloring, natural dyes have grown in favor in the food business (Batchold, et al., 2006). The goal of ongoing research is to create natural food dyes that are safe, stable, and compliant with regulations.

Sustainable Textiles and Fashion

Natural dyes are becoming more and more popular in the fashion industry as a way to make eco-friendly and sustainable clothes. Research addresses the incorporation of natural dyes into sustainable fashion supply chains (Dweck, 2002).

Applications connected to photovoltaics and UV protection

The use of natural dyes in dye-sensitized solar cells (DSSCs) has drawn attention (Al-Alwani, et al., 2015; Hao, et al., 2006). In addition to being a more environmentally friendly option to conventional silicon-based solar cells, these cells also help shield dyed fabrics from UV radiation that could cause lightening or fading (Chattopadhyay, et al.,



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2013; Grifoni, et al., 2009; Ibrahim, et al., 2013; Katarzyna, et al., 2008; Sarkar, 2004; Sun and Tang, 2011). These cells harvest solar energy using natural dyes.

Role of Natural Dyes in Nanotechnology

Advances in nanotechnology have resulted in the creation of materials at the nanoscale that has the ability to improve the characteristics of natural dyes. Natural dyes' color permanence, UV resistance, and other qualities can be enhanced by nanoparticles and nanostructures.

Optimization and Extraction

Many studies conducted in the present day have improved the effectiveness of natural dye extraction techniques using a variety of plant materials, fungi, and marine organisms (Adeel, et al., 2020; Adeel, et al., 2019; Al-MojnumShamim, et al., 2019; Batchold, et al., 2006; Borges, et al., 2012; Jiang, et al., 2019; Rahman, et al., 2013; Singh and Purohit, 2012; Wang, 2013). This includes creating brand-new extraction methods and maximizing color production by using enzymes. The extraction of dyes from a variety of natural sources, such as plants, insects, and minerals, has been the subject of numerous investigations. Researchers have developed and optimized extraction procedures to increase dye production and quality. Spectroscopy and chromatography are two characterization techniques that have been used to detect and analyse the chemical components that give natural dyes their colors. A general schematic extraction process for extracting natural using various extraction methods (Ghorab, et al., 2023) are as follows (Figure 3):

Assessment of Color Fastness

The fastness characteristics of various textiles determine their durability (Prabhu and Bhute, 2012; Mahmud-Ali, et al., 2012; Adeel, et al., 2020; Adeel, et al., 2019; Singh and Purohit, 2012). Using a Sasmira launder-O-meter, the color fastness of colored fabric samples to washing was evaluated in compliance with IS: 764-1984 techniques, which are based on IS-3 wash fastness method. A grey scale was used to assess the wash fastness grade in compliance with ISO-05-A02 (loss of shade depth) and ISO-105-AO3 (extent of staining). A computer-aided color measurement system linked to the relevant software and Macbeth 2020 was used to measure the staining and loss of color depth in order to cross-check the results. Using a manually operated crock meter and a grey scale in compliance with ISO-105-AO3 (staining extent), color fastness to rubbing (dry and wet) 12 was assessed in compliance with IS: 766-1984. To evaluate color fastness to light exposure, the IS: 2454-1984 approach was used. The sample and the eight blue wool standards (BS1006: BOI: 1978) were exposed to UV radiation in a Shirley MBTF Microsal fade-O-meter. A 500 watt Philips mercury bulb tungsten filament lamp that simulated daylight was part of the apparatus. The fading of each sample was assessed against the blue wool standards (1–8). The test specimen was sandwiched between two nearby pieces of textile fabric and stitched all the way around to create a composite specimen. In compliance with IS 971-1983, its color fastness to sweat was assessed. For half an hour at room temperature, each sample was submerged separately in an MLR 1:50 acidic/alkaline test solution. The sample was then loaded between the perspirometer, two glass plates weighing 4.5 kg (10 lbs). The apparatus was kept in the oven for four hours at $37\pm 2^{\circ}\text{C}$. At the end of this period, the specimen was removed and left to dry in the air at a temperature of no more than 60°C . The test samples were scored using grey scales according to color and staining changes. The rating of the samples for fastness to light and washing was done as follows:

Rating for the light fastness:

- 8 - Outstanding
- 7 - Excellent
- 6 - Very good
- 5 - Good
- 4 - Fairly good
- 3 - Fair
- 2 - Poor
- 1 - Very poor



**Naveen Kumar and Shyam Vir Singh****Rating for the washing fastness:**

- 5 - Excellent
- 4 - Good
- 3 - Fair
- 2 - Poor
- 1 - Very poor

Rating for staining:

- 5 - Negligible or no staining
- 4 - Slightly stained
- 3 - Noticeably stained
- 2 - Considerably stained
- 1 - Heavily stained

Lighting fastness and fading

Compared to synthetic dyes, natural dyes are typically less lightfast—that is, less likely to fade when exposed to light. This means that products dyed with natural dyes may fade more quickly when exposed to sunshine or other environmental influences. For fabrics and items meant for outdoor use, this is a serious problem.

Wash Fastness

Another thing to consider with natural dyes is how washable they are. Natural dyed fabrics might not hold their color well after several washings, which could restrict their use in clothing and other textiles that need to be laundered frequently.

Rubbing Fastness

Similar to the fastness mentioned above, rubbing fastness is significant for textile textiles that were measured using a grey scale and a manually controlled crock meter. The textiles' longevity is also impacted by this feature.

Perspiration Fastness

Under this fastness conditions, the textile sample was then positioned between two glass plates of the perspirometer with a force of 4.5 kg (10 lbs) (Singh and Purohit, 2012). The apparatus was kept in the oven for four hours at $37 \pm 2^\circ\text{C}$.

Mordants and Mordanting methods

A color fixative that helps to quickly bring out color is called a mordant. Mordants can be chemical, such as metallic salts, or botanical, such as plant extracts (Banna et al., 2019; Mahmud-Ali et al., 2012; Prabhu and Bhute, 2012; Wangatia et al., 2015; Singh and Purohit, 2012). The color produced by the dye is directly influenced by the mordant; hence, if two different acids or mordants are employed with the same dye, various colors will result. Compared to darker tones, lighter hues require less mordanting. Mordanting requires extreme caution since the color will fade if the mordant is not allowed to fully penetrate the fiber's shaft. The yarn or cloth needs to be mordanted right away after scouring for optimal results. Before the mordants are mixed with the yarns, they must be thoroughly dissolved and the yarns must be free of all grease and soap. There are many mordanting processes responsible to alter fastness and color shades of fabrics employed. Three main techniques for mordanting are typically employed: pre-mordanting (Anderson, 1971), simultaneous mordanting, also known as meta-mordanting, post-mordanting, etc. We can classify mordants as follows (Figure 4.):

Features of the dyed fabrics' colors

The determination of several characteristics for colored fabrics, such as lightness (L^*), redness-greenness value (a^*), yellowness-blueness value (b^*), chromaticity (c^*), and hue saturation (h^*), was done using CIEL^aa^b* values (Choudhary, 2015).



**Naveen Kumar and Shyam Vir Singh****Determination of surface colour strength (K/S value)**

By measuring the surface reflectance of the samples using a computer-aided Macbeth 2020 plus reflectance spectrophotometer and applying the Kubelka-Munk equation (Choudhary, 2015) with the aid of pertinent software, the K/S value of the undyed and dyed wool fabrics was ascertained:

$$K/S = (1 - R_{\lambda\max})^2 / 2R_{\lambda\max}$$

Where K represents the absorption coefficient, S the scattering coefficient, and $R_{\lambda\max}$ is the sample's surface reflectance value at a specific wavelength, or the point at which a given dye/color component absorbs the most.

Natural dye chemistry with textiles including mordant

In general, the chemistry of dyeing (Saxena and Raja, 2014; Samanta, 2020) describes how different fabrics are dyed based on the nature of the dye constituent and how it bonds with the functional groups in the fabric to form a complex that gives the fabric its color. However, if mordanting is used to change the color of the fabric to a different shade, three conditions must be met: pre-mordanting, meta-mordanting, and post-mordanting. In this case, if we follow the pre-mordanting condition, mordant (metallic or natural) will react first with fabrics and form a metallic complex with it after that dyeing process will occur in the presence of dye component which was isolated from the dye bearing plant or other natural resources, give the another complex of fabrics-mordant-dye component. For instance, if wool were a cloth, quercetin was a dye ingredient, and mordant was a metal; the reactive scheme might look something like this (Figure 5):

CONCLUSION

An investigation under present study concluded that natural dyes are sustainable, non-toxic, and beneficial resources with little impact on the environment. Because of this, and because of certain contemporary methods as well, the scientific community is becoming interested in using natural dyes in a range of established and emerging application fields. The people who work with natural dyes to color textile fabrics and preserve their sustainable qualities may find this paper useful. The information produced by these investigations could lay the groundwork for the natural dye industry to produce natural dyes on a commercial scale and use bioresources sustainably. From the different approaches, it can also be inferred that natural dyes can be employed to color fabrics on a modest scale, which could inspire young people and women in rural areas to launch a cottage business. Modern textile designers can easily use these lovely tones into today's color schemes, as they can easily satiate their artistic and creative cravings and help to create a more sustainable and environmentally friendly world, the study also makes suggestions for future research and useful tactics to promote the industry-wide use of natural dyes.

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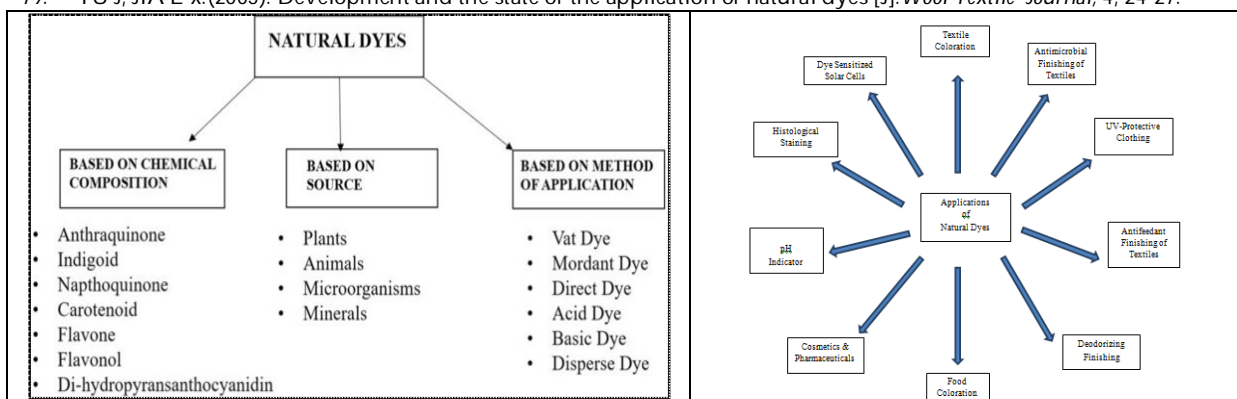


Figure 1: A general classification of natural dyes

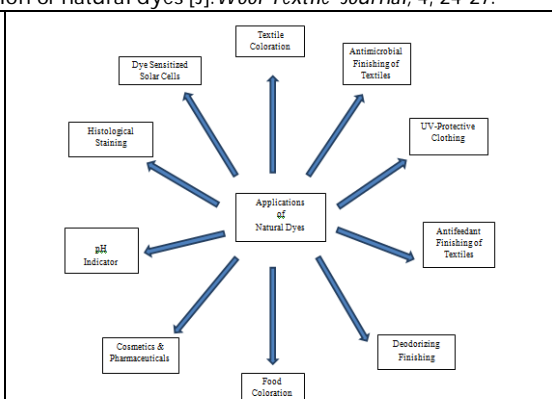


Figure 2: Various applications of natural dyes

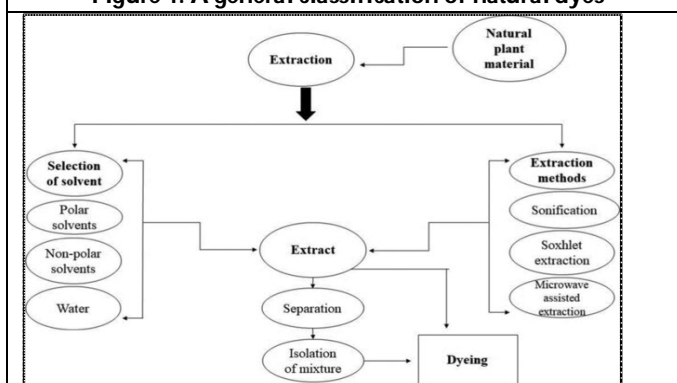


Figure 3: A general schematic extraction process for extracting natural dye using various extraction methods

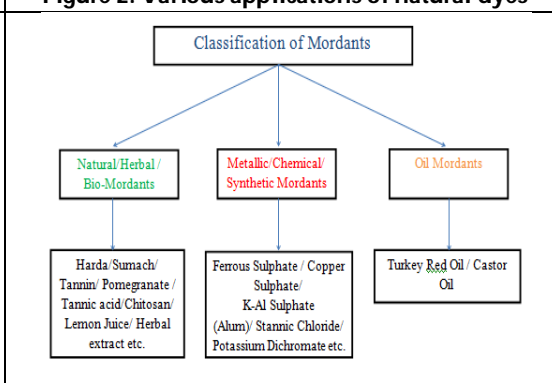


Figure 4. A General Classification of mordants

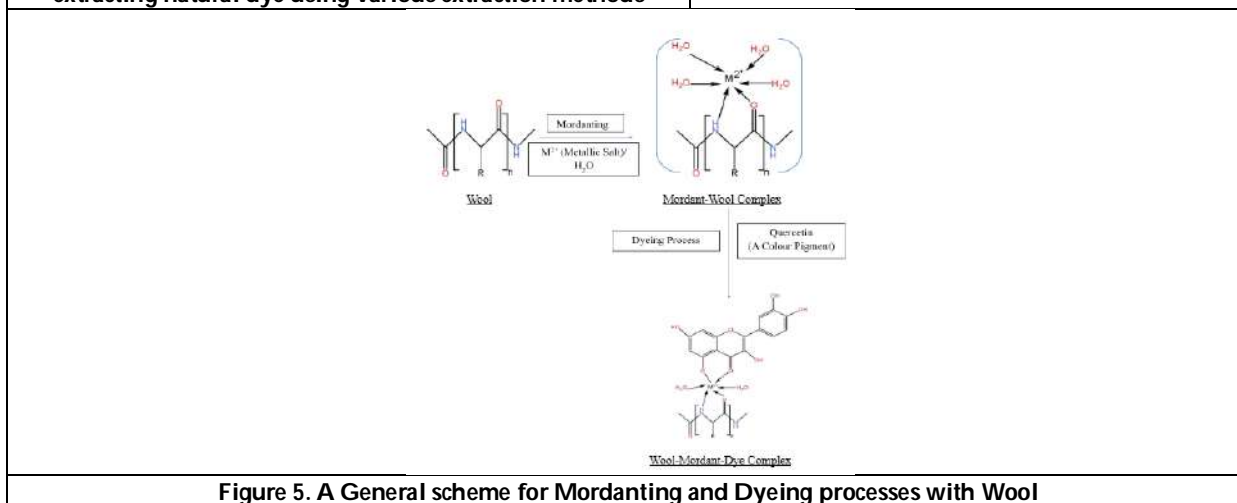


Figure 5. A General scheme for Mordanting and Dyeing processes with Wool





Effect of Symptoms Limited Exercise Training on Functional Status and Maximum Oxygen Consumption in Patients with Non-Operated Stable Coronary Artery Disease - A Pilot Randomized Controlled Trial

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ABSTRACT

Patients with coronary artery diseases suffers from symptoms like chest pain, breathlessness, fatigue, which may have an effect on their functional status and vo2 max. Physiotherapy intervention is one of the core components of cardiac rehabilitation, which can play a major role in improving functional status. Since there isn't a protocol for this, tailor- made exercise training protocol was given for these patients. A pilot randomized research was conducted to validate this protocol. The conventional group was advised to walk for minimum 30-40 minutes per day. The interventional group was taught 30-40 minutes of tailor-made exercise training once along with walking and provided a home exercise programme. Home diary was maintained to check adherence for both groups. Both groups were instructed to follow protocol for 5days/week for 3 months. Paired T-test showed significant improvement($P<0.05$) in the six-minute walk test duration, recovery period and maximum oxygen consumption in interventional group. Unpaired T-test showed significant improvement($P<0.05$) between the groups. There is an effect of symptoms limited exercise training to improve functional status and maximum oxygen consumption in patients with non-operated stable coronary artery disease.

Keywords: Exercise training, Coronary artery disease, Functional status, Maximum oxygen consumption



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INTRODUCTION

Coronary Artery Disease (CAD) is the most common type of heart disease, which is characterized by the presence of atherosclerosis in the epicardial coronary arteries [1-3]. Atherosclerotic plaques, the hallmark of atherosclerosis, progressively narrow the coronary artery lumen and impair ante grade myocardial blood flow [4-6]. The reduction in coronary artery flow may be symptomatic or asymptomatic, may occur with exertion or at rest, and may culminate in a myocardial infarction, depending on obstruction severity and the rapidity of its development [7,8]. Every year, an estimation of 17.7 million people died which is 31% of all global deaths are from having coronary artery disease. India is experiencing an escalating epidemic of CAD [9,10]. The contribution of CAD to total deaths and disease burden in India has almost doubled since 1990. Overall, CVD contributed to 28% of the total deaths in India in 2016, compared to 15% in 1990. [11] Cardiac Rehabilitation (CR) is a comprehensive treatment process that is centered on providing supervised aerobic exercise training, along with delivering ancillary services (e.g., nutrition counseling, smoking cessation, psychosocial support) for cardiovascular disease (CVD) patients. [12,13] Cardiac rehabilitation is used for cardiovascular diseases, it further divides into pre and post-operative rehabilitation. [14] Prescribing safe and progressive exercise programs in CR is critical to improving functional capacity, which is a key prognostic indicator for CVD patients. [15] Physiotherapy management is key component of cardiac rehabilitation, which helps to reduce dyspnea level, to improve endurance, to improve functional status and thus by improving overall quality of life. [16] Patients are suffering from symptoms like chest pain, breathlessness, fatigue, etc., which can have an overall negative effect on their functional status and quality of life. Many patients do not choose or are unwilling to undergo a surgical procedure due to the cost of surgery, their fear of surgery, and other factors, so they are treated only with medications. With regular exercise training patients may have improvement in functional status and maximum oxygen consumption. There are studies that show aerobic exercise can improve the functional status of patients, but there is no protocol-based exercise training to improve functional status and maximum oxygen consumption for patients with non-operated stable coronary artery disease. Since there isn't a protocol for this, we have a specially tailor-made exercise training for these patients. We conducted a pilot randomized research to validate this protocol. The protocol will be used to a larger population once it has been shown to be effective. Our objective of the study was to evaluate effect of symptoms limited exercise training on functional status in patients with non-operated stable coronary artery disease.

MATERIALS AND METHODS

This interventional pilot study was commenced after approval of institutional ethical committee and clinical trial registration.

The inclusion criteria were

- 1) Age group 40 to 70 years both men and women
- 2) Patients who were screened and diagnosed with stable coronary artery disease by interventional cardiologist
- 3) Severe stable coronary artery disease (>70% Blockage) who refused for CABG/PCI
- 4) Moderate stable coronary artery disease (>50-70% Blockage) who does not require PCI
- 5) Mild stable coronary artery disease (<50% Blockage).

The exclusion criteria were

- 1) Patients who were diagnosed with rheumatic heart disease.
- 2) Patients who were diagnosed with unstable coronary artery disease and required surgery.
- 3) Patients who were diagnosed for any associated pulmonary disease.
- 4) Patients who were suffering from any neurological conditions that affects upper limb movements and gait.
- 5) Patients with any lower limb musculoskeletal deformity affecting mobility.
- 6) Patients who were suffering from psychiatric disorders.



**Brijesh Acharya and Harihara Prakash****Sample size**

According to the literature, the standard deviation (SD) of the quality of life of CAD patients ranged from 12 to 18.^{17,18} Assuming a standard deviation of 15 and an 11-point difference as clinically important, a sample size of 30 per group will be required to attain 80% power while allowing for 5% type I error. Assuming a 20% loss to follow-up, the sample size inflated to 38 per group. The total sample size was 76. As this was pilot study 8-10% of total sample size was considered. Hence in this study, 20 patients were enrolled for pilot study.

Sampling method

Computerized randomization

Outcome measures

- 1) Six-minute walk test to evaluate functional status of patients[19].
- 2) Maximum oxygen consumption to evaluate myocardial oxygen demand [Equation: - Mean Peak $\text{VO}_2(\text{ml/kg/min}) = 4.948 + 0.023 * \text{Mean 6 MWD (meters)}$] [19]

METHODOLOGY

Patients who met the inclusion and exclusion criteria were recruited for the study. A total of 32 patients were screened for eligibility. Eight individuals did not match the inclusion requirements, three had lung disease, and one was denied participation. Twenty patients were randomly divided into two groups. Baseline data and outcome measures were evaluated following participation. The control group was told to walk for 30 minutes five days a week for three months. The interventional group received 30-40 minutes of symptoms-limited customised exercise intervention along with walking 5 days a week for three months. Once enrolled in the interventional group, all patients were provided a tailored exercise intervention. They were given a home exercise programme. They were asked to keep a home diary for reminders and follow-up purposes. Reminders were given by telephonic conversation every two weeks. Following a three-months follow-up, patients in both groups were assessed using outcome measures. Symptoms-limited exercise intervention was given to interventional group according to FITT protocol mentioned in table 1 to 3.

RESULTS

Paired T-test was used for within group analysis and unpaired T-test was used for between group analysis. Table 4 showed total of 10 (5 Male, 5 Female) patients with mean age (58.4 ± 6.43) in control group and 10 (6 Male, 4 Female) patients with mean age (51.1 ± 4.17) in interventional group were enrolled for the study. All patients had completed their course of exercise training for 3 months in both the groups respectively. Both groups have similar characteristics at baseline with respect to the severity of coronary artery disease. Table 5 showed there was no significant improvement in control group for vo_2 max, 6MWT recovery timings, 6MWT distance ($p > 0.05$). Table 6 showed there was significant improvement in interventional group for vo_2 max, 6MWT recovery timings, 6MWT distance ($p < 0.05$). Table 7 showed intergroup comparison, there was no significant improvement in control group for vo_2 max, 6MWT recovery timings, 6MWT distance ($p > 0.05$).

DISCUSSION

Cardiac rehabilitation has become a well-established treatment modality in patients with heart disease. The present study focused on effect of symptoms limited exercise training on functional status and maximum oxygen consumption in patients with non-operated coronary artery disease. Both qualities bear on important issues that are related to the goal of cardiac rehabilitation, namely restoration of normal daily functioning. This study showed





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significant improvement in interventional group in all the parameters, which suggest tailor made symptoms limited exercise intervention was effective. Meka N, Katragadda S, Cherian B, et al. did study on endurance exercise and resistance training in cardiovascular disease, which suggests overall improvement on functional status.[21] Lavie CJ, Thomas RJ, Squires RW, et al. did study on exercise training and cardiac rehabilitation in primary and secondary prevention of coronary heart disease, they concluded that Regular exercise training have a role in reducing CHD risk in both primary and secondary prevention.[22] In control group we could not found significant difference, but we achieved clinical significance within group. Though Kelley GA, Kelley KS. Efficacy of aerobic exercise on coronary heart disease risk factors, they concluded that aerobic exercise can reduce selected risk factors of CHD.[23] Present study concluded that there is positive effect of symptoms limited exercise training to improve functional status and maximum oxygen consumption in patients with non-operated stable coronary artery disease.

LIMITATIONS

One of the limitations of this study was the inability to give exercise training to patients in center-based cardiac rehabilitation due to barriers such as transportation, economical aspect and far distances of center to rural areas and reaching the center five times per week for twelve weeks. It can be an interest of consideration for future studies.

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Table-1 FITT Protocol

Week 1 to 6	
Frequency	5 days/week
Intensity	RHR +20–30 bpm/ upto 11 RPE
Time	30-40minutes/day
Type	endurance training

Table-2 FITT Protocol

Week 7 to 12	
Frequency	5 days/week
Intensity	RHR +20–30bpm/ 11 to 13 RPE
Time	30-40minutes/day
Type	endurance training

Table-3 Exercise training protocol

Warm-up Period: - (5 Minutes)		
Patient Position	Intervention	Frequency
Sitting	Long flexors stretch of upper limb	10 sec hold* 3 set
Sitting	Triceps stretch	10 sec hold* 3 set
Sitting	Wrist circling	10 sec hold* 3 set
Sitting	Ankle-toe movements	10 times * 3Set
Long sitting	Calf and hamstrings stretch	10 sec hold* 3 set
Aerobic exercise and endurance training (20 Minutes)		
Supine	Alternate hip and knee bending	10 times * 3Set
Side lying	Bilateral hip abduction	10 times * 3Set
Sitting	Alternate knee extension	10 times * 3Set





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Sitting	Thoracic Mobility Exercise - Flexion/extension - Abduction/adduction	10 times * 3Set
Sit to stand		10 times * 3Set
Marching		10 times * 3Set
Walking		15-20 minutes
Cool-down Period (5 Minutes)		
Sitting	Long flexors stretch of upper limb	10 sec hold* 3 set
Sitting	Triceps stretch	10 sec hold* 3 set
Sitting	Wrist circling	10 sec hold* 3 set
Sitting	Ankle-toe movements	10 times * 3Set
Long sitting	Calf and hamstrings stretch	10 sec hold* 3 set

Table-4 Baseline characteristics

	Control	Interventional
Age(Years)	58.4±6.43	51.1±4.17
Male	5	6
Female	5	4
Mild CAD	7	6
Moderate CAD	3	4
Duration of CAD(Months)	8±2	10±2

*CAD- Coronary artery disease

Table -5 Intra group analysis of control group

Parameters	Pre test Mean ± SD	Post 3 months Mean ± SD	P value
Vo2 max	12.407 ±0.87	14.415 ±1.39	0.05
6MWT Recovery min	6.4 ±0.7	5.4 ±0.84	0.07
6MWT Distance	318 ±25.73	340.7 ±34.54	0.06

*6MWT- 6 Minute walk test, Vo2 max- Maximum Oxygen consumption

Table- 6 Intra-group analysis of interventional group

Parameters	Pre test Mean ± SD	Post 3 months Mean ± SD	P value
Vo2 max	14.562 ±0.67	21.315 ±.39	<0.001
6MWT Recovery min	5.9 ± 0.99	2.4 ± 0.52	<0.001
6MWT Distance	357.8 ± 32.39	443.6 ± 32.41	<0.001

*6MWT- 6 Minute walk test, Vo2 max- Maximum Oxygen consumption

Table- 7 Inter-group comparison between control and interventional at 3 months

Parameters	Control Mean ± SD	Interventional Mean ± SD	P-Value
Vo2 max	6.08±1.12	8.3±1.29	0.06
6MWT Recovery min	3±0.81	1±0.56	0.08
6MWT Distance	60±5.62	75±2.63	0.10

*6MWT- 6 Minute walk test, Vo2 max- Maximum Oxygen consumption





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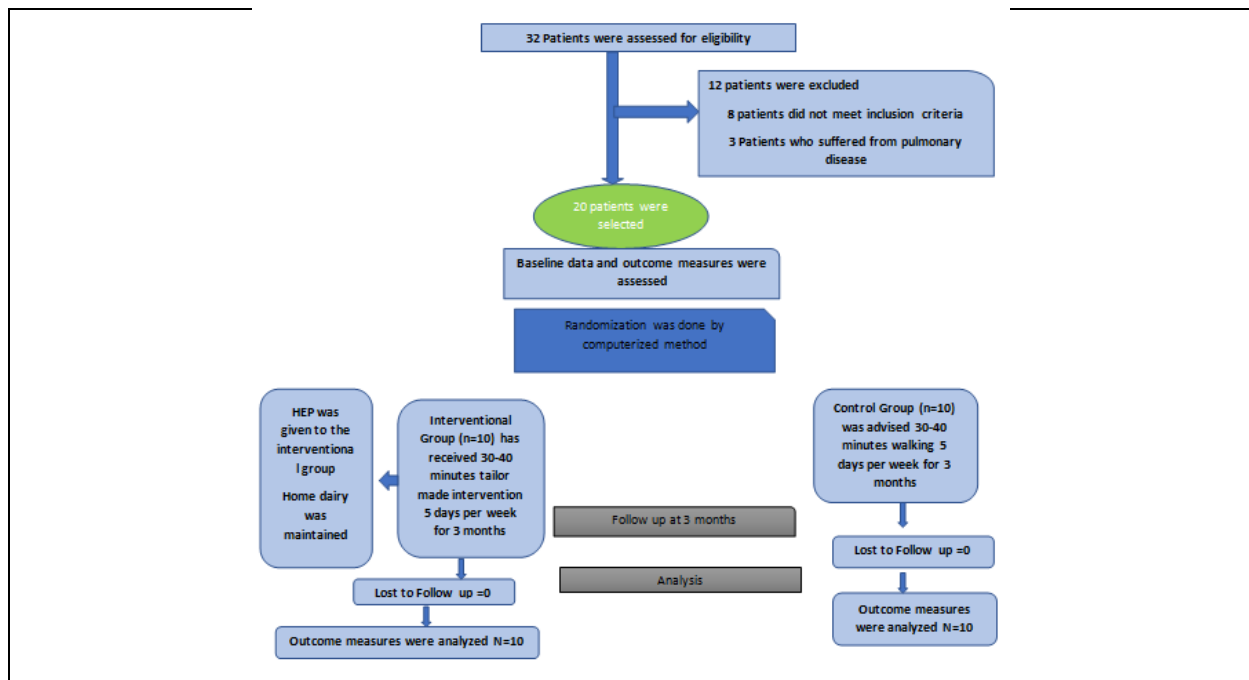


Fig :1 CONSORT Diagram





Fig:2 Patient intervention figures.





Impact of Social-Economic Conditions by Weekly Markets in Improving Sustainability among Rural Villages in Kanchipuram District of Tamilnadu

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ABSTRACT

For thousands of farmers, the weekly markets have been a source of income. However, it has been noted that farmers who have long participated directly in these weekly marketplaces are not experiencing major social or economic growth. This study aims to comprehend the significance of weekly markets in the lives of thousands of farmers who depend on them as their primary source of income. The socioeconomic effects of rural weekly markets on farmers' lifestyles are examined in this research. In the weekly market, farmers' average monthly revenue and financial standing are rising with time. Farmers have greater opportunities to engage with other vendors and consumers through the market. They are now more involved in market-related activities, supporting one another when things go tough, and they are getting greater moral support from others, such as vendors and buyers.

Keywords: Farmers Weekly Market, Rural Market, Socio economic conditions

INTRODUCTION

Following independence, rural India operated like a self-sufficient village economy until 1960. There was close proximity between the producers and the customers. Agri inputs and output services dominated the rural market with the advent of the green revolution in 1960, with the exception of a few products from distant areas. (Das, 2018) The most distinctive way for the people of each nation-state to come together and exchange and maintain their cultural, social, political, and economic facets is through village "Haats," or markets. Haats are ill-defined structures



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that offer venues for local craftspeople and artists to exhibit their work in addition to selling their products, which may only be accessible in certain areas (Deogam, 2023). Haats is defined as a "public assembly of commodity buyers and sellers, meeting at a designated or customary location at regular intervals." The majority of these periodic markets only take place once every week. Haats serve as both physical marketplaces for the sale of agricultural surplus and retail locations for the purchase of everyday necessities and farmingsupplies. In India's rural areas, there are roughly 42,000 haats. One haat typically serves 20 to 50 towns, has over 300 stores, and receives over 4,500 visits (Chatterjee, 2023). In order to promote and maintain the pace of rural economic growth, agricultural marketing infrastructure is essential. Just as important to improved agricultural performance as farming itself is marketing. The decision to create a marketable agricultural product is the first step in the agribusiness process, which includes all pre- and post-harvest activities such as grading, value addition, packaging, processing, and shipping. Farm produce gains value from these activities (Jeyaramya, 2022). Weekly village markets are a frequent sight in Tamil Nadu, dating back to the emperor era. Some of the most well-known ones to this day include Ponmalaisanthai in Trichy, Anthiyursanthai in Erode, Pochampallisanthai in Dharmapuri, and Pallavaramsanthai in Chennai. Tamil Nadu's weekly market has a lengthy history. Because it provides jobs, revenue, and status for its members, it plays a crucial role in the development of farmers, coolies, and the impoverished (Kumaresan and Manivannan, 2019).

Significance of Haats

Various Channels of Selling to Farmers

The impact of farmers' markets: Over time, individual farms tend to specialize in producing particular categories of agricultural goods, which they then sell at such markets. Because those farms make good use of their comparative advantages—such as their close proximity to markets, infrastructure, favorable environmental conditions, etc.—their financial situation is better. Farmers' markets have a big influence on pricing because they establish prices in a traditional way—based on supply and demand. Farmers' markets offer better costs than wholesale, which makes them more likely to choose to sell their goods directly to consumers. It is significant to highlight that while transportation costs associated with farmers' market sales are somewhat lower for producers than for trading groups, they still require some transportation, therefore producers do not own the entire difference in these prices (Tošović-Stevanović et al., 2020).

RESEARCH AREA

The district of Kanchipuram is located on Tamil Nadu's northeast coast. The district is bordered to the east by the Bay of Bengal, to the west by the districts of Vellore and Thiruvannamalai, to the north by the districts of Thiruvallur and Chennai, and to the south by the district of Villuppuram. It is located between latitudes 11° 00' and 12° 00' and longitudes 77° 28' and 78° 50'. The district is 4, 43, 210 hectares in total size, with 57 kilometers of shoreline. Pre-monsoon rainfall is consistent throughout the district, while it is heavier toward the shore than in the interior. There will be a hardship situation if the monsoon is unsuccessful. The two main contributors, the Northeast and Southwest monsoons, are 54% and 36%, respectively. A typical monsoon brings 1200 mm of rain to the District. With 47% of the population working in agriculture, it is the most common occupation. While other crops including groundnuts, sugarcane, cereals and millets, and pulses are also grown, paddy is the main crop. The primary soil resources found in the Kanchipuram District include Clay Loam, Red Sandy Loam, and Saline Coastal Alluvium. The Palar River, tanks, and wells are the primary irrigation sources (Kalpana et al., 2019). Five Prospective villages were identified in all the taluks of the district. In 5 villages 50 prospective entrepreneurs from each village were identified and these entrepreneurs were selected based on simple random sampling technique. Based on collected data 20 incomplete responses were eliminated and 230 responses were finalized.

Specific objectives

- To identify the nature of entrepreneurship practice in selected rural villages in Kanchipuram District.
- To find out the socio and economic condition of the Stall owners under study.
- To identify the impact of Gender and economic condition from the weekly Santhai



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- To identify the recognizing weekly santhai as source of income across Gender

Data analysis

Responses obtained from the returned questionnaires were separately coded and entered on the computer terminal for use in computer tabulations. SPSS (Statistical Package for Social Sciences) was used to show relationships between various variables. Tests of significance in independent sample were calculated using specific SPSS to check the emotional intelligence of the students.

Tools for Analysis

In this study, some related tools of statistics have been used for the purpose of analysis. Percentage, F-Test, T-Test and are used. The uses of all these techniques have been made as per the requirement of the analysis.

RESULTS AND DISCUSSIONS

Out of total 230 respondents, 74.3 per cent of the respondents are males and the remaining is coming under the category of females. Majority of respondents are male. 40.4 per cent of the respondents are in the age group of 31-40 years, 25.2 per cent of respondents are fall under the age group of 41-50 years and the least percentage of respondents are in the age group of above 60 years. It is observed that most of the respondents (40.4 per cent) are in the age group of 31-40. Out of total (230) respondents, 82 per cent of respondents are living in Kanchipuram taluk and only 2.6 per cent of respondents located in uttiramalur taluk. It is found that most of the respondents are living in Kanchipuram taluk. Of total respondents, 46.5 per cent of respondents are having Tiled house, 41.7 per cent of respondents having concrete house and 5.2 per cent of respondents having Thatched house. Out of 230 respondents, 64.8 per cent of the respondents not having any loan, rest of them having loan for developing their life. 59.9 per cent of respondents facing the major problem which is Poor lighting, 15.2 per cent of respondent's choice is insufficient water and bathroom facility, and least number of respondents problem is traffic issue.

Relationship between Gender and Sources of Income

Null Hypothesis (Ho): There is no significant between the Sources of income and gender. T test has been applied at 5 per cent level of significance to examine the hypothesis and the computed results are presented in the following table. It is stated from the above table that among the two categories of gender, female respondents are having maximum level of mean score towards Sources of income. It is noted from the T test analysis that the null hypothesis is accepted. Hence, It is found that there is no significant between the sources of income and gender of selected respondents in the study area. Reboul from his research the findings theoretically emphasize the gendered earmarking of debt and credit, since the meanings and applications of debt and credit differ for men and women. They also support the gendered dimension of behaviour, since caste, poverty, and familial ties significantly influence women's behaviour while having little effect on men. Finally, these findings raise concerns about the explicit targeting of women by microcredit schemes, which is likely to intensify the role that women play in managing scarcity and deepen the link between debt and poverty for women. (Reboul et al., 2021)

Gender and Weekly income

In order to find the relationship between the gender of the respondents and Weekly income, the following hypotheses are formulated.

Null Hypothesis (Ho): There is no significant between the weekly income and Gender of selected respondents in the study area. T test has been applied at 5 per cent level of significance to examine the hypothesis and the computed results are presented in the following table. It is stated from the above table that among the two categories of gender, male respondents are having maximum level of mean score towards weekly of income. It is noted from the T test analysis that the null hypothesis is accepted. Hence, It is found that there is no significant between the weekly income and gender of selected respondents in the study area. Devaki research indicates the majority of farm women



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had low levels of yearly income, had animals, were exposed to the media, were motivated by economic factors, and interacted with locals and cosmopolitans. They had a high degree of extension agency contact and a medium level of social activity. (Devaki et al., 2015)

Relationship between Gender and Adequate Transport facility

Null Hypothesis (Ho): There is no significant between the Adequate Transport facility and gender. T test has been applied at 5 per cent level of significance to examine the hypothesis and the computed results are presented in the following table. It is stated from the above table that among the two categories of gender, female respondents are having maximum level of mean score towards adequate transport facility. It is noted from the T test analysis that the null hypothesis is rejected. Hence, It is found that there is a significant between the adequate transport facility and gender of selected respondents in the study area. According to the Elakiya Study, when it comes to gender analysis, vans were used by more than half (55.88%) of the male agripreneurs for transportation, followed by two-wheelers (41.18%) and lorries (2.94%). When it came to female agripreneurs, vans were used by more than half (56.86%) of them, followed by two-wheelers (40.20%) and lorries (2.94%). The agripreneurs' business, the customers, and the quantity of output all influence the manner of transportation. For transportation, the majority of agribusiness owners utilized two-wheelers because they were limited to the local area and the quantity of products they collected was smaller. Products relating to coir, coconut flakes, and bio inputs were delivered by truck. The people that sold to contractors and distributors set up the transportation and split the expense. This could be the cause of the aforementioned. (Elakkiya and Asokhan, 2021)

Gender and various challenges

In order to find the relationship between the gender of the respondents and various challenges, the following hypotheses are formulated.

Null Hypothesis (Ho)

There is no significant between the various challenges and Gender of selected respondents in the study area. T test has been applied at 5 per cent level of significance to examine the hypothesis and the computed results are presented in the following table. It is stated from the above table that among the two categories of gender, male respondents are having maximum level of mean score towards weekly of income. It is noted from the T test analysis that the null hypothesis is accepted. Hence, It is found that there is no significant between the various challenges and gender of selected respondents in the study area. According to the Kumerasan study, the weekly market is typically held in the village center, on public roadsides, or in places of worship, but it lacks a formal structure and organization. Many conflicts arise between vendors and customers as well as between the market's contractors during operating hours. Various regional names for the village weekly market include Haats, Shandy, Santhai, Bazaar, and rural markets. There are, however, between 21000 and 47000 markets in the nation. Weekly village markets are a frequent sight in Tamil Nadu, dating back to the emperor era. (Kumaresan and Manivannan, 2019)

CONCLUSION

From the study it is found that weekly santhai plays a significant role in improving the financial status of the farmers and it is important medium in developing sustainably and improve rural economy. The farmers typically attend the market on a seasonal basis because their livelihoods depend on the availability of seasonal fruits, vegetables, and other agricultural products. Their financial situation is getting better even if they are unable to use the earnings to buy additional assets. Like everyone else, the farmers are interacting socially with other market goers, exchanging knowledge and offering encouragement. Through market activities, the weekly markets continue to provide a means of subsistence and a forum for social interaction between market participants.





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Table-1: Socio economic conditions of Weekly village santhai respondents

Particulars	Classification	Number of Respondents	Percentage
Gender	Male	171	74.3
	Female	59	25.7
Age	20-30 years	46	20.0
	31-40 years	93	40.4
	41-50 years	58	25.2
	51-60 years	29	12.6
	Above 60 years	4	1.7
Taluk	Kancheepuram	190	82.6
	Uttrimerur	6	2.6
	Walajabad	34	14.8
Type of House	Tiled	107	46.5
	Thatched	12	5.2
	Mud	15	6.5
	Concrete	96	41.7
Do you have loan?	Yes	81	35.2
	No	149	64.8
Loan amount	Less than 50000	32	39.5
	50001-100000	24	29.6
	More than 100000	25	30.9





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Sufficient Transport facility	Yes	209	90.9
	No	21	9.1
Market places	Iyyempattai	24	10.4
	Baluchetty	44	19.1
	Dusi	31	13.5
	Kathirpur	44	19.1
	Kuruvimali	87	37.8
	Bargaining	30	13.0
Various challenges	Insufficient Water & bathroom facility	35	15.2
	Poor Lighting	137	59.6
	Traffic problems	28	12.2
	Livestock	81	35.2
Income Sources	Selling in Santhai	116	50.4
	Contract farming	18	7.8
	Hawkers	15	6.5

Table : 2

S.No	Gender	Mean Score	SD	F Value	P Value
1.	Male	1.84	.777	2.403	.122
2.	Female	1.90	.941		

Table: 3 Relationship between Gender and Weekly income

S.No	Gender	Mean Score	SD	F Value	P Value
1.	Male	2.32	1.196	0.008	.928
2.	Female	1.95	1.319		

Table : 4

S.No	Gender	Mean Score	SD	F Value	P Value
1.	Male	1.08	.266	7.168	.002
2.	Female	1.14	.345		

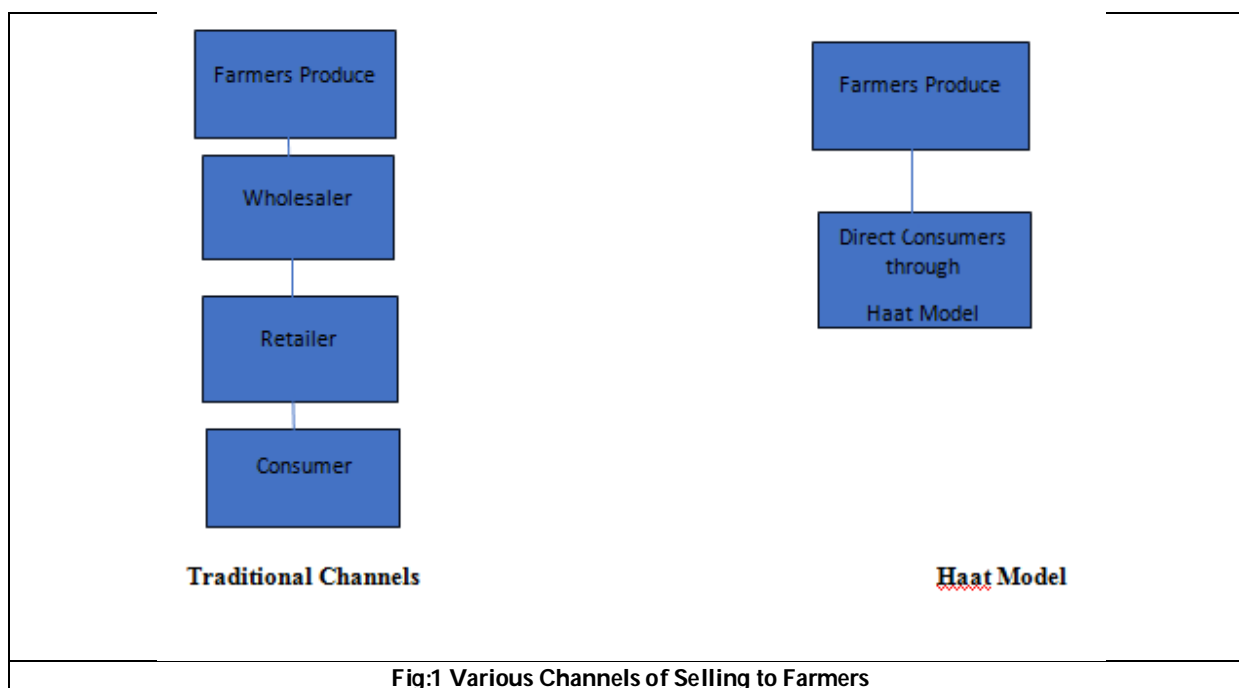
Table: 5 Relationship between Gender and Various challenges

S.No	Gender	Mean Score	SD	F Value	P Value
1.	Male	2.75	.853	.030	.862
2.	Female	2.58	.814		





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Breast Cancer Mammogram Image Classification using Transfer Learning

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ABSTRACT

Transfer learning is a powerful technique to utilize an already existing pre-trained deep learning model which was previously trained for some exclusively different task than the problem in question. This research focus on the concept of transfer learning where a previously trained convolutional neural network based model was fine tuned to perform classification of breast cancer mammograms. A modified mini DDSM dataset was used. The images were pre-processed and a random split has been performed on images for training and testing purpose. The cross entropy loss criterion was used to check performance of the model. Stochastic Gradient Descent algorithm was also used for fitting the proposed model with 0.001 learning rate. A decay LR scheduler was used after each 7th epoch to revise the learning rate by 0.1 factor. The contribution of this paper can be summarized in two parts. First, the ResNet50 was implemented by with generalized weights (IMAGENET1K_V1) and with only three layers unfreeze and further fine-tuned for the target problem. Second, the model after fine tuning classifying breast cancer mammograms with 90.94% average training accuracy and 95.19% average validation accuracy in 25 epoch training for finding malignancy. By training the model up to 50 epochs the proposed model achieve 96.79% average training accuracy and 99.93% average validation accuracy. Due to the high accuracy achieved by the model on a small dataset by limited training epochs, the proposed model can be used to detect malignancy in breast mammograms.

Keywords: Breast Cancer, Classification, Mammograms, Transfer Learning, Deep Learning, Fine Tuning





INTRODUCTION

Breast cancer detection is considered as a leading research area because breast cancer is the second leading cause of mortality worldwide [1]. Screening mammography is a renowned and promising tool to detect malignancies in the breast cancer. This can be helpful in early detection of breast cancer and to reduce mortality rate [2]. Breast cancer detection using digital mammography is an image classification problem in the area of computer vision. This problem can be solved by using object detection and object recognition algorithms of computer vision. Innovations and advancements in the field of deep learning are working as a fuel in the area biomedical image processing. Breast cancer detection with substantial accuracy at the early stage of the disease is most important. Research indicate that digital mammography based breast cancer detection systems showing average 86.9% and 88.93% sensitivity and specificity respectively [3] and need further improvement. Research suggests that deep learning based breast cancer detection algorithms showing promising results [4-11]. A vast amount of data is required for training of deep learning models. Being an emerging field, not much official biomedical digital image datasets and benchmarking datasets are available for deep learning researchers. To solve the scarcity of data a comparatively new sub field of deep learning called transfer learning is used these days. Transfer learning is a promising deep learning method which is used to train deep neural network when large training dataset is not available. In this method, a deep learning model is first trained on an existing pre-trained model, initialize its weights for recognizing primitive features such as edges, lines, corners and texture. Further this same model is fine tuned for another task. Classification of breast mammograms is a challenging research problem of image classification area because the Region of Interest (ROI) which include lesion and masses (approximately 100 x 100 pixels) are located in a very small portion of the whole image of breast mammogram (approximately 4000 x 3000 pixels) [18]. Due to this reason in most of the researches whole mammograms are pre-processed (clipped and annotated) to focus on ROI only [8, 12-16,19-22]. This clipping approach has limitation to have intervention of radiographers to mark ROI region in whole mammograms. In the present study we have used whole mammography images and transfer learning for classification of mammograms to detect malignancy which need no human intervention.

MATERIAL AND METHODS

Dataset

A modified mini DDSM [17] dataset has been used to perform this experimentation. MiniDDSM is a lightweight thumbnail image dataset having three classes Normal, Benign and Malignant. Each class has lossless JPEG images with MLO and CC views of left and right breast of each case. The present experiment emphasizes on classification of tumours so we have discarded the normal cases from the dataset. The dataset is pre-processed and augmented using various transformation functions. Images are randomly cropped and resized to 224 pixel size, the available images are horizontally flipped and normalized. The complete dataset has been divided into 70:30 train-test split for further experimentation.

Hardware and Software

We used Google Colab for Google Computer Engine backend (GPU) with Python 3 provided with 12.7GB RAM, 15.0GB GPU RAM and 78.2GB Disk Storage, for the training, validation and testing process. TorchVision0.16.0 is used to perform the experimentation

Proposed Method

In the present work we have proposed a transfer learning based breast tumour classification system. Transfer learning addresses the performance degradation issue of deep learning models due to lack of data for proper training. We used PyTorch version 2.1.0 to design our classification model. This is a five stage detection system. The five stages include pre-processing of images, segmentation, feature extraction, feature selection and classification.





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Deep Network Architecture

The deep networks imitate human brain and composed of multiple layers of neurons. In deep networks the starting layers are convolution layers. These convolution layers are used to extract important features from the images. These are followed by pooling layers to perform subsampling of the feature maps identified by the convolution layers. The last layers of deep networks are fully connected layers which perform classification of images on the basis of sampled feature maps. The deep learning models imitate the human brain. It is composed of multiple layers. Starting layers are convolution layers which are used for feature extraction. The following few pooling layers performs subsampling of the feature maps. The final layers called fully connected layers perform classification. In the present work we have used transfer learning in which an already existing pre-trained deep neural network is used to solve the problem concern by performing changes in the layers and adjusting the parameters of few layers while keeping other layers frozen. In this experiment we have used ResNet50 pre-trained model to perform breast cancer detection and classification. The architecture of the ResNet50 is given in Table 1. We keep top layers freeze and layer 4, fully connected layer and average pool layer have remain unfrozen. To make the model adapt to our case, we switched the previous output to one output with a sigmoid activation function since our case is a binary classification. Several trials were applied to establish the suitable parameters for fine-tuning, compiling, and fitting the models. The images were pre-processed and a random split has been performed on images for training and testing purpose. The cross entropy loss criterion was used to check performance of the model. Stochastic Gradient Descent algorithm was also used for fitting the proposed model with 0.001 learning rate. A decay LR scheduler was used after each 7th epoch to revise the learning rate by 0.1 factor. Table1 shows the final and optimal parameters. The weights of the final model used for transfer learning are given in Table2. The fine tuning and fitting parameters used for in our work is given in Table 3.

RESULTS AND DISCUSSION

In this section, we have presented a comparative performance analysis for breast cancer detection. The proposed deep network was initially trained and validated for 25 epochs. At each epoch during the training phase the accuracy of the model is identified and after 25 epochs the best model state showing highest accuracy during the training was selected. The validation steps are performed for this best model. This model show average 20.65% training loss and 90.94% training accuracy with minimum training loss 7.53% and maximum accuracy 97.74% respectively. The model shows average 11.57% validation loss and 95.19% average validation accuracy. At the best end, the model shows 1.25% validation loss and 99.89% validation accuracy. Further, the model was trained for 50 epochs. The model shows 10.03% and 1.77% average loss in training and validation respectively. A significant 96.79% and 99.93% accuracy was seen during training and validation phase. Figure 1 showing the performance of the proposed model for 25 and 50 epochs of training and validation. The training and validation loss observed during 25 epoch and 50 epoch execution is shown in Figure 2. Figure 3 is showing training and validation accuracy seen during the 25 epoch and 50 epoch execution respectively. In this figure a trend line is also plotted. The coefficient of determination (R^2) for 25 epochs to 50 epoch execution is 1 for both validation loss and prediction accuracy which indicates that the model is perfectly predicting the outcomes. The R^2 is a number between 0 and 1 that measures how well a statistical model predicts an outcome. There are several other methods also available to evaluate the results of classification process. In the present paper we have used accuracy, sensitivity, and specificity and confusion matrix. The confusion matrix was created on the basis of the results of the proposed model. From this confusion matrix we have calculated accuracy, sensitivity and specificity by using True Positive (TP), False Positive (FP), True Negative (TN) and False Negative (FN). True Positive (TP) is the total number of correctly identified benign and malignant breast tumour. False Positive (FP) is the total number of breast tumour identified as malignant but are benign. True Negative (TN) is the total number of cases correctly identified as benign. False Negative (FN) is the total number of images identified as benign but is malignant.

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \% \text{ (Equation 1)}$$

$$\text{Sensitivity} = \frac{TP}{FN+TP} \% \text{ (Equation 2)}$$





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$$\text{Specificity} = \frac{TN}{FP+TN} \% \text{ (Equation 3)}$$

The confusion matrix of the model is given in Figure 4. The values of TP =1318, FP =2, FN=2 and TN=2347 are identified using this confusion matrix. The sensitivity(99.84%) and specificity(99.91%) are identified using equation 2 and equation 3 respectively.

CONCLUSION

A breast cancer prediction detection model using deep neural network has been proposed. Transfer learning has been used in which a pre-trained ResNet50 model was used to identify parameters of the model. ResNet50 was modified by unfrozen last three layers, fine tuning and fitting parameters was done for the targeted problem. We collected benign and malignant tumour images from miniDDSM dataset. These images were pre-processed and augmented such that we managed to reach 99.93% breast cancer detection accuracy, 99.84% sensitivity and 99.91% specificity. The performance of the model can be improved further by using other efficient pre-trained model and by using other pre-processing techniques for images, which is one of our future research directions.

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Table 1. ResNet50 architecture and model weights

Layer Name	Output Size	50 layers
Conv1	112x112	7x7, 64, stride 2
Conv2.x	56x56	3x3 max pool, stride 2
		$\begin{bmatrix} 1 \times 1, 64 \\ 3 \times 3, 64 \\ 1 \times 1, 256 \end{bmatrix} \times 3$
Conv3.x	28x28	$\begin{bmatrix} 1 \times 1, 128 \\ 3 \times 3, 128 \\ 1 \times 1, 512 \end{bmatrix} \times 4$
Conv4.x	14x14	$\begin{bmatrix} 1 \times 1, 256 \\ 3 \times 3, 256 \\ 1 \times 1, 1024 \end{bmatrix} \times 6$
Conv5.x	7x7	$\begin{bmatrix} 1 \times 1, 512 \\ 3 \times 3, 512 \\ 1 \times 1, 2048 \end{bmatrix} \times 3$
	1x1	Average pool, 1000-d fc, softmax
FLOPs		3.8x10 ⁹

Table 2. ResNet50 model weights used for experimentation

```

ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
)

```





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```

)
(1): BasicBlock(
  (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
  (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
)
)
(layer2): Sequential(
  (0): BasicBlock(
    (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
    (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (relu): ReLU(inplace=True)
    (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (downsample): Sequential(
      (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=False)
      (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (1): BasicBlock(
    (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (relu): ReLU(inplace=True)
    (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  )
)
(layer3): Sequential(
  (0): BasicBlock(
    (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
    (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (relu): ReLU(inplace=True)
    (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (downsample): Sequential(
      (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
      (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (1): BasicBlock(
    (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (relu): ReLU(inplace=True)
    (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  )
)
)

```

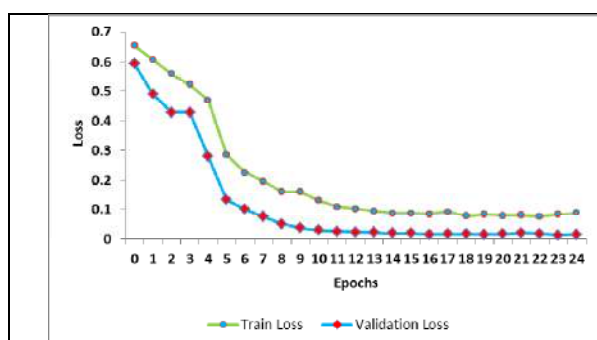
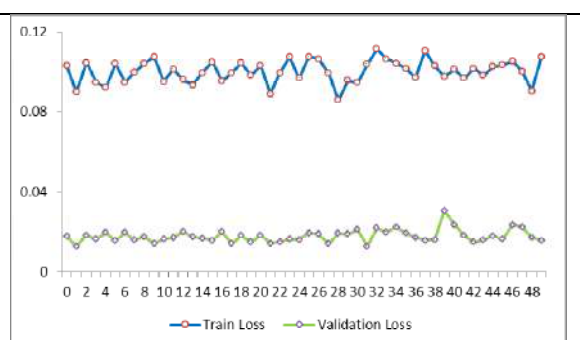




```
(layer4): Sequential(
  (0): BasicBlock(
    (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
    (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (relu): ReLU(inplace=True)
    (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (downsample): Sequential(
      (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
      (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (1): BasicBlock(
    (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (relu): ReLU(inplace=True)
    (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=512, out_features=2, bias=True)
)
```

Table 3. Fine Tuning and Fitting Parameters

Optimizer	SGD
Learning Rate	0.001
Momentum	0.9
Loss Function	Cross Entropy Loss
From Logits	True
Metrics	accuracy
Number of Epoch	25/50
Validation Steps	3/4

**Figure 1. Performance of the proposed model- a) Average training loss observed during 25 epoch execution.****Figure 1. b) Validation loss observed during 50 epoch execution.**

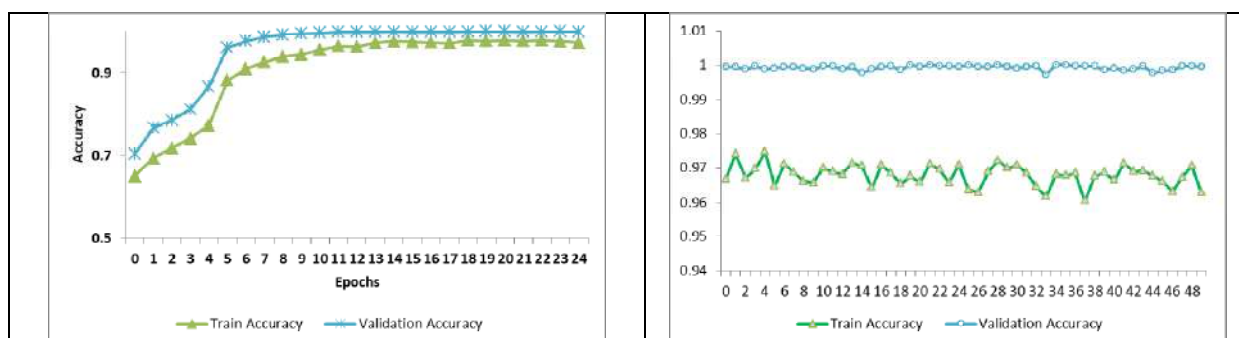


Figure 1. c) Training accuracy for 50 epoch execution

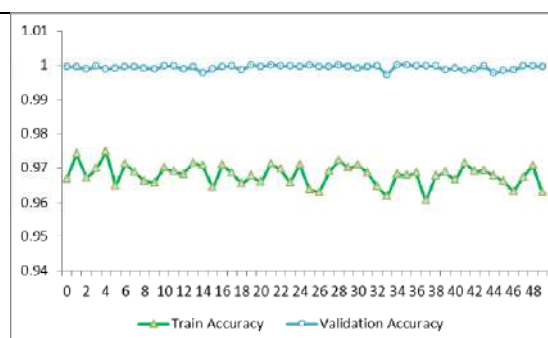


Figure 1. d)

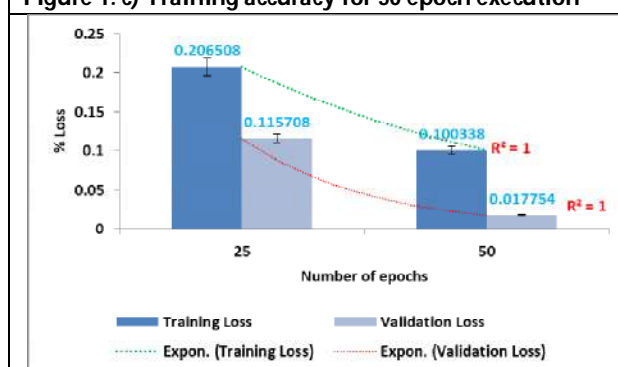


Figure 2. Comparison of Training and Validation loss observed during 25 epochs and 50 epochs of execution.

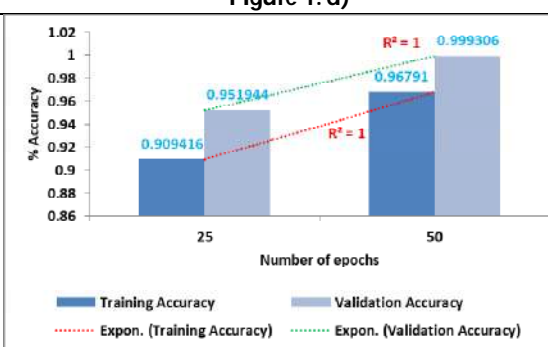


Figure 3. Comparison of Training and Validation accuracy observed during 25 epochs and 50 epochs of execution.

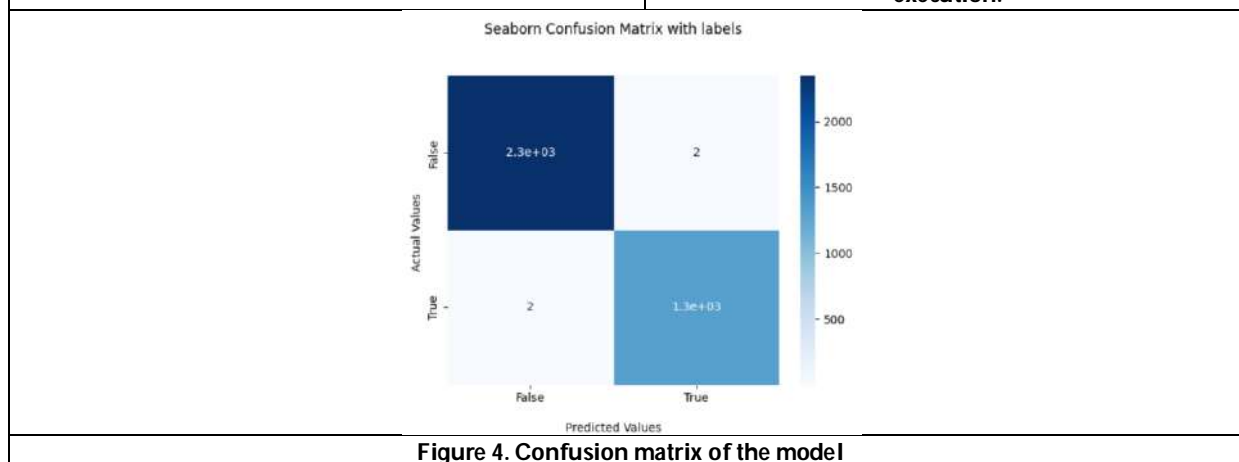


Figure 4. Confusion matrix of the model





The Mediating Effect of Marital Adjustment and Social Support on the Relationship between Partner Abuse and General Health

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ABSTRACT

The purpose of the study was to determine the mediating effect of marital adjustment and social support on the relationship between partner abuse and general health among Sikkimese married women. Utilizing the quantitative method via sequential mediation, data were obtained from 400 Sikkimese married women within the age group of 18-40 years as early adults and 41-60 years as middle adults from the rural and urban areas of Sikkim. For the sequential mediation, the present study employed a partial least square method. To find out the prediction of GHQ Positively phrased items (GHQPP) and GHQ Negatively phrased items (GHQNP) from partner abuse, marital adjustment, and social support were considered as mediators with/without demographic variables. The only possible path for the sequential mediation was Partner abuse -> Marital adjustment -> Social support -> GHQPP/GHQNP. Results revealed a significant effect on the prediction of GHQPP from Partner abuse with Marital adjustment and social support as mediators with/without demographic variables. In addition, results also revealed a significant effect on the prediction of GHQNP from Partner Abuse with Marital Adjustment and Social Support as mediators with/ without demographic variables.

Keywords: Marital Adjustment, Social Support, Partnerabuse, General Health

INTRODUCTION

Marriage is a significant life event that occupies a remarkable place in the lives of many women and men (Berscheid & Regan, 2005). Marriage has been identified to be one of the most powerful predictors of happiness and well-being.



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Besides, Argyle and Furnham (1983) explained that "Marriage is the most important form of social support for most people, greater than friends or other emotional and marital support and companionship". According to the study by Brigoli & Sandoval (2023), there are important correlations between married couples' well-being and leading satisfying lives, as well as between married couples' well-being and marital satisfaction. Marital adjustment is defined as the mental condition in which spouses have an overall feeling of happiness and satisfaction with their marriage and with each other (Sinha & Mukerjee, 1990). As a result, it calls for a satisfying relationship between spouses that is characterized by reciprocal concern, care, understanding, and acceptance. It entails being able to effectively negotiate and cope with the different transitions, obligations, and duties that come with being married. Marital adjustment is a continuing process that requires communication, flexibility, and collaborative effort from both parties. Each marriage is unique, and success is defined differently by different people and it's important to remember that every marriage is different, and the meaning of marital success may differ from couple to couple. What works for one marriage might not work for the next (Bentler & Newcomb, 1978; Glenn & Uecker, 2010). Marital adjustment is a process that arises in the course of a couple's relationship because it is essential for the development of behavioural norms, personality traits, and relational models (Aminjafari, *et al.*, 2012). Cobb (1976) defined social support as "the feeling of belonging to a network of communication and mutual responsibility, as well as the knowledge that one is respected and cherished by loved ones". Social support can be distinguished by its sources like friends, family, teachers, romantic partners, relatives, neighbours, co-workers, organizations, etc. Each support an individual receives from any source is beneficial for well-being and for promoting positive feelings (Chu, *et al.*, 2010). Prezza & Pacilli (2002) found that married men perceive more support for a certain person than married women, proving that marriage benefits men. On the other hand, women are better able to rebuild their support system after a marriage ends due to separation or the death of one partner. Likewise, the concept of the mediating role of social support and marital adjustment in marriage describes how certain variables, such as individuals' well-being, communication and emotional well-being, intimacy and conflict, cohesiveness and marriage satisfaction, and quality of the marriage, can affect the relationship between the various factors (Nihayah *et al.*, 2023; Tönbul & Malkoç, 2023).

As a "bridge" between different relationship variables, marital adjustment and social support can affect how couples handle opportunities and obstacles, which in turn shapes the nature and course of their relationship (Caldwell & Bloom, 1982; Mert, 2018). Muslima & Herawati (2018) in their study revealed that social support and marital adjustment affect an individual's marriage quality. It was also reported that social support had a significant positive relationship with marital adjustment, moreover, marital adjustment was positively correlated with marital quality. Sometimes, there comes a situation where everyone experiences ups and downs in their marriage. Spouses are happier, healthier, and live longer in secure, happy relationships. However, other foundations of well-being are compromised when the partnership fails (Karney & Bradbury, 2020). One of the common marital problems faced by married women in India is intimate partner violence, also known as partner violence/abuse from their partners (Bhat & Ullman, 2014; Ahmed-Ghosh, 2004; Nadda *et al.*, 2018). Partner abuse is one kind of domestic violence. Partner abuse refers to the battering that occurs in a relationship between a couple who is married and living together. Research has suggested that the forms of partner abuse that occur are not the same for all couples but it is experienced differently by each individual (Dobash & Dobash, 1979; Indu *et al.*, 2021). There are many different forms of partner abuse and a person may be subjected to one or more than one form of violence. It includes physical violence, sexual violence, psychological abuse, emotional abuse, and many more (Kahol, 2003; Ahuja, 2009; Aminjafari *et al.*, 2012; Devi, 2005). Moreover, the physical, mental, and emotional well-being of an individual is directly impacted by partner abuse, which means that there is a close correlation between general health and relationship abuse. An individual's overall health is harmed in several ways when they experience abuse from their relationship (Svavarsdóttir, & Orlygsdóttir, 2009). The term "general health" refers to an individual's total well-being, which includes physical, mental, and emotional elements. It is a multidimensional term involving a variety of aspects that contribute to an individual's overall health state. It is essential to remember that the overall health and well-being of an individual vary from person to person and are interconnected. It can be impacted by various combinations of genetic influences, lifestyle choices, socioeconomic considerations, and the general social and





physical environment. Therefore, maintaining and developing overall health necessitates a multifaceted approach that covers all areas of well-being (Huppert & So, 2013; Ruggeri *et al.*, 2020).

Objectives of the study

- 1.To determine the role of marital adjustment and social support in the prediction of GHQ positively phrased items (GHQPP) from partner abuse among the samples.
- 2.To determine the role of marital adjustment and social support in the prediction of GHQ negatively phrased (GHQNP) items from partner abuse among the samples.

Hypothesis of the study

- 1.The relationship between partner abuse and GHQ positively phrased items (GHQPP) among the samples will be mediated by marital adjustment and social support.
- 2.The relationship between partner abuse and GHQ negatively phrased items (GHQNP) among the samples will be mediated by marital adjustment and social support.

METHODS AND PROCEDURE

A random sample of 400 married Sikkimese women, in early and middle adulthood from urban and rural areas, was selected. Only women who were married and living with their spouses during data collection were included. Participants received information about the study and provided written consent. The tools, translated in both English and Nepali through back-translation, were administered in a quiet, private setting to ensure confidentiality and privacy.

Psychological Tools Used

The present study employed standardized psychological tools to assess partner abuse, marital adjustment, social support, and general health - The Community Composite Abuse Scale by Loxton *et al.*, 2013, the Revised Dyadic Adjustment Scale by Busby *et al.*, 1995, the Multidimensional scale of perceived social support by Zimet *et al.*, 1988 and the General Health Questionnaire by Goldberg, 1972. All of them were found to have excellent reliability and validity.

RESULTS AND DISCUSSION

Result Table 1 shows the path coefficients of sequential mediation for the prediction of GHQ Positively phrased items (GHQPP) with demographics from Partner abuse. Figure 1 showed the path diagram of sequential mediation employing a partial least square method for the prediction of GHQ Positively Phrased items (GHQPP) from Partner Abuse with Marital Adjustment and Social Support as mediators with demographic variables. Demographic factors, including educational level, occupation, socioeconomic status, marital status, religion, and others, were considered during the preliminary analysis. However, analyses that controlled for these factors were included to summarize and clarify the findings of the current study. The findings suggest that social support and marital adjustment play a key mediating role in mitigating the effects of partner abuse on mental health, as measured by positively phrased items on the General Health Questionnaire (GHQPP). Research consistently highlights that social support functions as a protective factor that can buffer against stress and enhance well-being (Fleet & Hiebert-Murphy, 2013). Social support, especially in collectivistic and closely-knit communities, provides individuals with emotional and practical resources that help reduce the negative psychological impact of abuse. Marital adjustment also emerges as a crucial mediator, especially in regions like Sikkim, where strong cultural and familial connections can amplify the importance of harmonious marital relationships. A well-adjusted marital relationship may offer a sense of stability and security, which can protect individuals from the adverse mental health consequences associated with partner abuse (Ghoroghi *et al.*, 2012). In conclusion, partner abuse and good mental health outcomes are mediated by social support and marital adjustment as social support will always positively and significantly be associated with marital



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adjustment (Abbas *et al.*, 2019; Fleet & Hiebert-Murphy, 2013). Therefore, as hypothesized there was found to be a mediating role of marital adjustment and social support in the relationship between partner abuse and general health positively phrased items among the samples. The Result Table 2 shows the path coefficients of sequential mediation for the prediction of GHQ Negatively phrased items (GHQNP) with demographics from Partner abuse. Figure 2 showed the path diagram of sequential mediation employing a partial least square method for the prediction of GHQ Negatively Phrased items (GHQNP) from Partner Abuse with Marital Adjustment and Social Support as mediators with demographic variables. The results of sequential mediation (Table 2 and Figure 3) revealed a significant effect of the direct, indirect, and total effect on the prediction of GHQNP from partner abuse with marital adjustment and social support as mediators with/without demographic variables. The findings of the direct effect indicate that there is a positive relationship between partner abuse and GHQNP. In other words, as the levels of partner abuse increase, the level of GHQNP also increases. Other research has suggested that married women who are exposed to any type of partner abuse are associated with higher rates of all health risk behaviours, and poor health, and might also experience different disorders like depression, drug dependence, generalized anxiety disorder, post-traumatic stress disorder, etc than the women who have never experienced partner violence (Bonomi *et al.*, 2006; Clemente-Teixeira *et al.*, 2022; Tolman and Rosen, 2001).

Similar findings by Coker *et al.*, (2000) reported that women who had experienced intimate partner abuse were far more likely to report having poor physical and mental health. According to the study conducted by Shilpa & Suman (2022), the main reason for the perpetration of partner abuse was found to be the alcohol use by their spouses. Other than that, the other reason was the partners' personality behaviours like unstable mood, short-tempered, suspiciousness, and manipulation and half of the women mentioned extramarital involvement of their partners. The findings are also supported by the prior study where they reported that partner abuse has been associated with the negative well-being of an individual (Grundström *et al.*, 2021; Adams & Beeble, 2019). In addition, İyiyaydın & Sümer (2021) on their study reported that through the mediating effects of intimate partner rejection and psychological marital adjustment, the results showed that intimate partner behavioural control was substantially and indirectly linked with marital adjustment. Moreover, psychological maladjustment and marital adjustment were directly impacted by rejection from an intimate partner. Importantly, their study showed that the association between intimate partner control and marital adjustment was also mediated sequentially by psychological maladjustment and intimate partner rejection. Although having positive relationships, the direct effect of partner abuse on GHQNP reduces from (.42) to an indirect effect (.06) with the inclusion of mediators (social support and marital adjustment). Social support and marital adjustment are important factors in enhancing general well-being and lowering poor health consequences. These findings are similar to findings indicating that fostering social support and marital adjustment are vital components for maintaining a healthy lifestyle and well-being (Muslima and Herawati, 2019; Gyasi *et al.*, 2019). However, the present findings are contradicted by prior study conducted by (Soulsby and Bennett, 2015). Therefore, as hypothesized there was found to be the mediating role of social support and adjustment in the relationship between partner violence and general health negatively phrased items among the samples.

CONCLUSION

The findings in the present study revealed that the association between partner abuse and general health among the samples was shown to be mediated by social support and marital adjustment, according to the sequential mediation results. With marital adjustment and social support acting as mediators, the first results of a partial least square approach demonstrated the considerable impact of GHQPP and GHQNP from partner abuse. In addition, the prediction of GHQPP and GHQNP from partner abuse was shown to be significantly impacted by social support and marital adjustment, both of which acted as mediators with and without demographic covariates. By identifying these mediators, the research highlights two critical pathways that could be targeted to mitigate the negative health impacts of partner abuse. Social support and marital adjustment don't just influence individual well-being but serve as protective factors in complex relational environments. Interventions focused on strengthening social support





systems and enhancing marital adjustment could therefore be vital in improving the general health of those affected by partner abuse.

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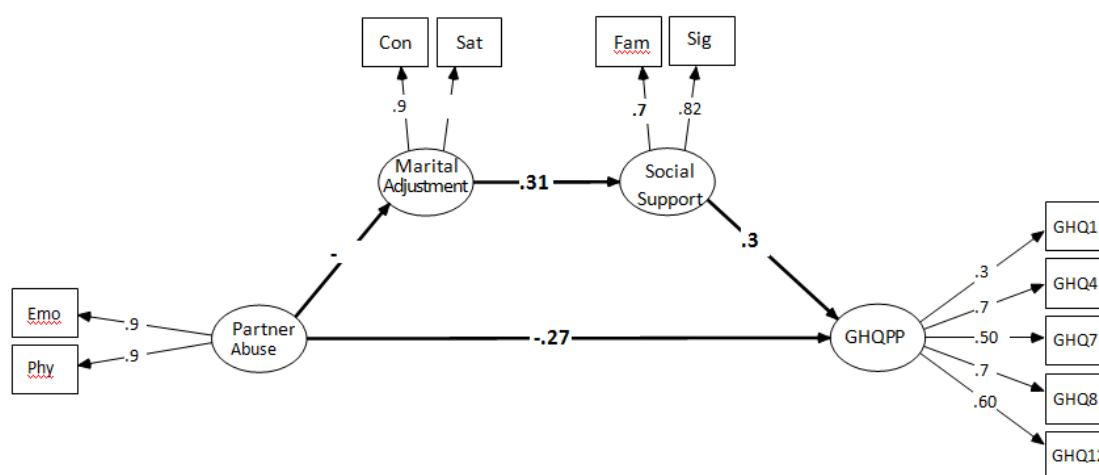


Lalfamkima Varte *et al.*,**Table.1: The path coefficients of sequential mediation for the prediction of GHQ Positively phrased items (GHQPP) with demographics from Partner abuse.**

	Direct effect	Indirect effect	Total effect
Partner abuse -> marital adjustment -> social support -> GHQ positively phrased items	-.27	-.06	-.33
Partner abuse -> marital adjustment -> social support	-	-.19	-.19
Partner abuse -> marital adjustment	-.60	-	-.60
Marital adjustment -> social support -> GHQ positively phrased items	-	.10	.10
Marital adjustment -> social support	-	-	.31
Social support -> GHQ positively phrased items	.33	-	.33

Table.2: The path coefficients of sequential mediation for the prediction of GHQ Negatively phrased items (GHQNP) with demographics from Partner abuse.

	Direct effect	Indirect effect	Total effect
Partner abuse -> marital adjustment -> social support -> GHQ negatively phrased items	.43	.05	.47
Partner abuse -> marital adjustment -> social support	-	-.19	-.19
Partner abuse -> marital adjustment	-.59	-	-.59
Marital adjustment -> social support -> GHQ negatively phrased items	-	-.08	-.08
Marital adjustment -> social support	.32	-	.32
Social support -> GHQ negatively phrased items	-.25	-	-.25

**Figure.1: The path diagram of sequential mediation employing a partial least square method for the prediction of GHQ Positively Phrased items (GHQPP) from Partner Abuse with Marital Adjustment and Social Support as mediators with demographic variables.**

[Phy= Physical abuse; Emo= Emotional abuse; Con= Marital Consensus; Sat= Marital Satisfaction; Fam= Family





support; Sig= Significant others; GHQPP= General Health Questionnaire Positively Phrased items; GHQ1= GHQ Positively phrased item 1; GHQ4= GHQ Positively phrased item 4; GHQ7= GHQ Positively phrased item 7; GHQ8= GHQ Positively phrased item 8; GHQ12= GHQ Positively phrased item 12].

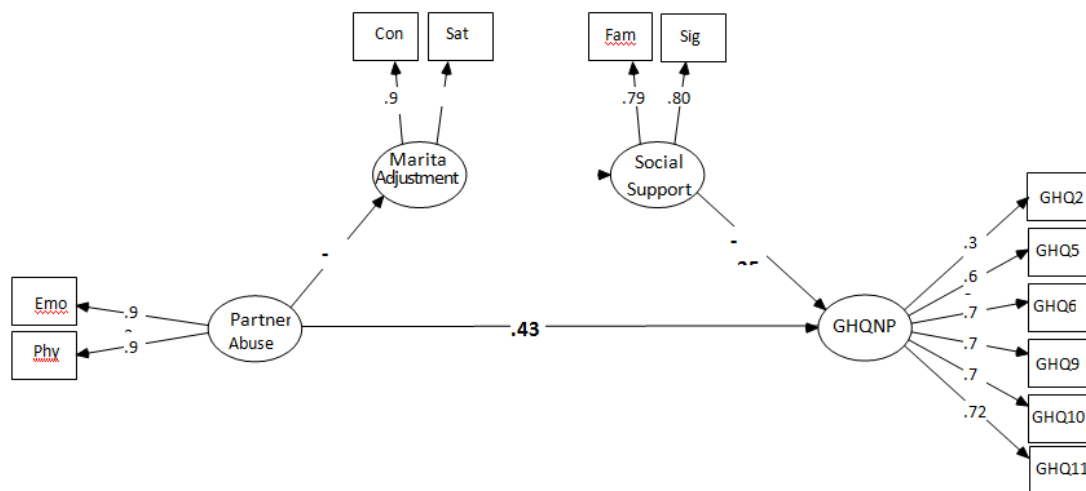


Figure.2: The path diagram of sequential mediation employing a partial least square method for the prediction of GHQ Negatively Phrased items (GHQNP) from Partner Abuse with Marital Adjustment and Social Support as mediators with demographic variables.

[Phy= Physical abuse; Emo= Emotional abuse; Con= Marital Consensus; Sat= Marital Satisfaction; Fam= Family support; Sig= Significant others; GHQNP= General Health Questionnaire Negatively Phrased items; GHQ2= GHQ Negatively phrased item 2; GHQ5= GHQ Negatively phrased item 5; GHQ6= GHQ Negatively phrased item 6; GHQ9= GHQ





Signature Forgery Detection using Neural Networks

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ABSTRACT

The increasing reliance on digital transactions and online authentication processes has underscored the need for robust signature verification systems. This paper presents a comprehensive framework for detecting forged signatures using advanced preprocessing techniques, feature extraction, and machine learning-based classification. The preprocessing pipeline includes grayscale conversion, noise reduction with Gaussian filtering, binarization via Otsu's thresholding, and bounding box extraction for signature isolation. The feature extraction phase focuses on seven key signature characteristics—eccentricity, skewness, solidity, kurtosis, centroid position, signature coverage, and bounding box dimensions—each analyzed for its contribution to distinguishing genuine signatures from forgeries. High performance on test data is achieved when a Multi-Layer Perceptron (MLP) neural network model is used for classification. The system's integration with Google Colab ensures scalability, while feature importance analysis demonstrates the critical role of eccentricity and skewness in detecting forgeries. The proposed system showcases high accuracy, providing a reliable tool for signature verification in real-time and bulk testing environments.

Keywords: Digital Signature Verification, Forgery Detection, Image Preprocessing, Feature Extraction, Neural Networks, Eccentricity, Skewness, Google Colab Integration.





INTRODUCTION

Verification of signatures is an essential part of digital security and is widely used in document authentication, banking, and contracts. Automated systems that can reliably differentiate between real and fake signatures are becoming more and more necessary as digital transactions increase. Generally speaking, there are two types of procedures for verifying signatures: offline verification involves examining scanned photographs of the signatures. This paper develops an automated system for differentiating between authentic and counterfeit signatures, addressing the difficulties in offline signature verification by fusing machine learning and image processing. The problem of signature verification is complicated by factors such as variations in writing style, image quality, and distortions from scanning. Traditional methods using geometric features often struggle with such variability. To overcome these challenges, modern approaches incorporate machine learning, which can learn complex patterns and generalize effectively across different signatures. This study develops a framework for offline signature verification that uses preprocessing steps (such as converting images to grayscale, Gaussian smoothing, and Otsu's thresholding) to prepare the signature images for feature extraction. Important characteristics are retrieved to characterize the geometry and distribution of the signature, including eccentricity, solidity, skewness, and centroid. A Multi-Layer Perceptron (MLP) neural network is then trained on labeled data using these attributes as input to determine if a signature is authentic or fake. Using an MLP improves the model's capacity to distinguish between signatures by enabling it to learn nonlinear correlations in the data. A distinctive aspect of the system is its integration with Google Colab and Google Drive, enabling cloud-based data storage and model training. This setup facilitates easy access to data, secure storage, and efficient collaboration, especially when working with large datasets. Additionally, the modular structure of the code ensures flexibility, with each part of the system (preprocessing, feature extraction, classification) easily adjustable. Classification accuracy and other indicators are used to evaluate the system's performance, showing how well it separates authentic signatures from fakes. Convolutional neural networks (CNNs) for feature learning, hyperparameter tweaking, and data augmentation could be used in future developments to further increase model performance. This study advances the field of signature verification by giving an automated approach that integrates machine learning and image processing, with potential uses in document authentication and safe online transactions.

MATERIALS AND METHODS

This study employs a thorough offline signature verification methodology that consists of several steps: data collecting, preprocessing, feature extraction, neural network model creation, and performance assessment. This systematic framework combines image processing techniques and machine learning to achieve high accuracy in distinguishing between genuine and forged signatures.

Data Collection and Organization

The dataset used in this study consists of a collection of genuine and forged signature images. The signatures come from a group of people, and for training and testing purposes, both real (authentic) and fake signatures are used. The dataset is structured to ensure that the system can learn to differentiate between genuine and forged signatures from various individuals. To facilitate efficient data handling, the dataset is organized into separate directories for genuine and forged signatures. This organization ensures that the data is well-structured for supervised learning, with each set of images labeled accordingly. The signature images are stored on Google Drive (Figure 3) (Figure 4), ensuring easy access and secure storage for further processing. This setup is integrated with Google Colab, which allows for scalable and flexible processing of large datasets directly from the cloud.

Preprocessing Steps

Preprocessing transforms raw pictures into a format that the machine learning model can efficiently examine, making it an essential stage in the verification of signatures. To improve the signature's features and minimize noise, the following preprocessing techniques are used on the digital signature images:





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1. **Grayscale Conversion:** Signature images are first converted to grayscale, usually from RGB color. By eliminating color information from the image, grayscale conversion streamlines it while maintaining the crucial intensity information of the signature and lowering computing complexity. This stage guarantees that the structure of the signature can be recorded without superfluous color elements.
2. **Gaussian Filtering for Noise Reduction:** After converting to grayscale, the image is subjected to **Gaussian smoothing** to reduce noise. Gaussian filtering helps to blur the image slightly, removing small variations in pixel intensity that could result from scanning artifacts, paper texture, or distortions in the signature. This step ensures that only the signature itself is analyzed, free from irrelevant noise.
3. **Otsu's Thresholding for Binarization:** The next preprocessing step is Otsu's thresholding, which automatically picks the best threshold value to turn the grayscale image into a binary (black and white) image. By separating the foreground (signature) from the background, this procedure makes the signature stand out and streamlines feature extraction.
4. **Inversion of Image Colors:** The binary image is inverted, ensuring that the signature is displayed in white against a black background. This inversion standardizes the image and prepares it for feature extraction, as the signature typically appears as a bright stroke on a dark background in most signature verification systems.
5. **Bounding Box Extraction:** To focus solely on the signature, a bounding box is drawn around the region containing the signature. This step crops out unnecessary whitespace or background noise, reducing the image size and improving the accuracy of subsequent feature extraction. These preprocessing steps are crucial in ensuring that the signature images are in a standardized and clean format, allowing for more accurate analysis by the machine learning model.

Feature Extraction

Extracting significant features that capture the essential elements of the signature comes next after preprocessing. By using these characteristics as input, the machine learning model is able to distinguish between authentic and fake signatures. The following features are extracted:

1. **Eccentricity:** Eccentricity measures the elongation of the signature. Forged signatures often exhibit exaggerated strokes, leading to higher eccentricity values compared to genuine signatures, which tend to be more compact and natural. This feature helps in identifying forgeries based on their stretched or skewed appearance.
2. **Skewness:** Skewness quantifies the asymmetry of the signature distribution along the x and y axes. Genuine signatures typically have balanced skewness values, reflecting the natural flow of writing. In contrast, forged signatures may show irregular distributions, indicating deviations from the genuine writing style.
3. **Kurtosis:** Kurtosis measures the "tailedness" of the intensity distribution of the signature. High kurtosis indicates that the signature has sharp peaks and long tails in its intensity distribution, which is often observed in forged signatures due to inconsistent or exaggerated strokes.
4. **Solidity:** Solidity is the ratio of the area of the signature to its convex hull area, providing a measure of the signature's compactness. Genuine signatures tend to have a higher solidity ratio, reflecting the smooth and continuous nature of the stroke. In contrast, forged signatures may show more irregularities in stroke density, leading to lower solidity values.
5. **Signature Coverage:** Signature coverage represents the proportion of the image area covered by the signature. A higher ratio of coverage is typical of genuine signatures, as they tend to occupy more space on the paper. Forgeries, especially those made quickly or clumsily, might leave more white space.
6. **Centroid Position:** The centroid of the signature is the geometric center of the signature region. This feature is useful for detecting misalignments or irregularities in the signature placement. Inconsistencies in centroid position are often observed in forgeries, where the signature might not be placed as naturally as in genuine ones. The extracted features are then organized into a **feature vector** for each signature. These vectors are stored in **CSV files** for further analysis and are used to train the neural network model.

Neural Network Model Design

The system's main component is a Multi-Layer Perceptron (MLP) neural network, which uses the extracted feature vectors as input to determine if the signatures are authentic or fake. The following layers make up the model:





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1. **Input Layer:** The input layer receives a feature vector of size 9, representing the 9 extracted features from each signature.
2. **Hidden Layers:** There are three hidden levels in the network, each containing seven, seven, and thirty neurons. Multiple hidden layers with tanh activation functions give the model non-linearity, which helps it discover intricate relationships and patterns in the feature data.
3. **Output Layer:** Two neurons with softmax activity, which stand in for the two classes of fabricated (0) and authentic (1), make up the output layer. Probabilistic outputs, which show the likelihood that the signature belongs to each class, are provided by Softmax.
4. **Optimizer and Loss Function:** Whereas the Adam optimizer is used for efficient gradient-based optimization, categorical cross-entropy is used as the loss function, making it suitable for multi-class classification problems. To reduce the loss function and increase classification accuracy, the model is trained in batches by repeatedly going through the dataset (epochs).

Evaluation and Testing

Both training and testing datasets are used to assess the model once it has been trained. Accuracy, precision, recall, and F1-score are calculated as part of the evaluation process to assess the model's performance. To explain the model's classification findings and get insight into false positives and false negatives, a confusion matrix is used. Two evaluation modes are used to test the system:

1. **Batch Evaluation:** The model processes a batch of signature images to assess the overall accuracy and performance. This mode is useful for evaluating the model on a large dataset and comparing different models or configurations.
2. **Real-Time Testing:** In this mode, the model is used to classify a single signature image. This is ideal for practical applications where a new signature needs to be verified in real-time, such as in digital document signing platforms or banking systems.

Implementation Details

The entire system is implemented using Python libraries, including numpy, pandas, scipy, and tensorflow for numerical operations and machine learning tasks. Matplotlib, skimage, and PIL are used for image loading, processing, and visualization. The code is hosted and run in Google Colab, with Google Drive integrated for easy data management. This cloud-based environment enables seamless access to datasets and efficient collaboration, making the system scalable for large datasets and multiple users

RESULTS AND DISCUSSIONS

Results and Evaluation The results of the offline signature verification system's application, including the neural network model's performance metrics, are presented in this part. The efficiency of the preprocessing pipeline, feature extraction, and machine learning model in differentiating between authentic and fake signatures is assessed in this section. Numerous performance measurements, comparisons with baseline techniques, and suggestions for possible enhancements are the main topics of the evaluation.

Performance Metrics

Several common measures, which are crucial for assessing classification models in machine learning applications, were used to evaluate the model's performance. The following are the main evaluation metrics:

1. **Accuracy:** The ratio of accurately identified signatures (both authentic and fraudulent) to all signatures. An overall indicator of the model's performance is accuracy.
2. **Precision:** Precision quantifies the percentage of authentic signatures that are accurately identified as genuine, or true positives, out of all instances that are classed as positive. This measure is crucial for comprehending how well the model prevents false positives, or incorrectly identifying counterfeit signatures as authentic.

Precision = (True Positives) / (True Positives + False Positives)





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3. **Recall (Sensitivity):** The percentage of true positives among all real positive cases (authentic signatures) is measured by recall. High recall means that the model is capable of detecting the majority of real signatures, even if it misclassifies some fake ones.

$$\text{Recall} = (\text{True Positives}) / (\text{True Positives} + \text{False Negatives})$$
4. **F1-Score:** A balanced indicator of the model's performance, the F1-score is the harmonic mean of precision and recall, particularly in cases where the two classes (genuine and forged) are out of balance.

$$\text{F1-Score} = (2 * (\text{Precision} * \text{Recall})) / (\text{Precision} + \text{Recall})$$
5. **Confusion Matrix:** This graphic depicts the model's classification performance by displaying the number of true positives, false positives, true negatives, and false negatives. This matrix aids in identifying the model's weak points, especially when it comes to differentiating between authentic and fake signatures.
6. **ROC Curve and AUC:** The Receiver Operating Characteristic (ROC) curve and the Area Under the Curve (AUC), the model's capacity to differentiate between the two classes is also evaluated using the ROC curve and AUC. An elevated AUC value signifies superior model performance. These metrics are used to give a thorough picture of how well the model classifies signatures.

Training Performance

The neural network model was trained over a set number of epochs using labeled authentic and counterfeit signatures. The loss function was minimized using the Adam optimizer, and the model was trained to modify the weights via back propagation. During the training phase, the loss gradually decreased, and the model's accuracy improved, as evidenced by the training logs. The following points highlight key observations during training:

1. **Convergence:** The model's loss curve showed a steady decrease, indicating that the training process was converging. This suggests that the model was successfully learning from the training data.
2. **Overfitting:** The model's performance was routinely checked against a hold-out validation set to prevent overfitting. The findings demonstrated that the model does a good job of generalizing to new data, and no discernible overfitting was found during training. The validation accuracy stayed relatively close to the training accuracy, indicating that the model was picking up generalizable patterns rather than memorizing the training data.
3. **Training Time:** The training process was efficient, with the model converging within a reasonable number of epochs (e.g., 20-30 epochs). The use of **batch training** and an efficient optimizer like Adam ensured that the model did not take excessively long to train.

Feature Analysis and Justification

Analysis of the role features play in the categorization process is a crucial component of this study. A number of methods, such as correlation analysis and permutation importance, were employed to determine which features have the most influence on forgery detection.

- **Eccentricity and skewness** identified as the most significant traits, with eccentricity alone resulting in a 15% loss in accuracy. Since forgeries often alter the natural elongation of authentic autographs, the significance of eccentricity in identifying fake signatures is well-established.
- **Skewness**, which measures asymmetries in the distribution of strokes in a signature, was particularly important because forgeries frequently have uneven stroke patterns.
- Complementary information on the density and compactness of the signature was offered by solidity and coverage. Accuracy decreased by 10% when these traits were removed, demonstrating their value in detecting discrepancies in variations in compactness and stroke density.
- **kurtosis** also proved beneficial, particularly in capturing subtle variations in the tail distributions of forged signatures. The combination of eccentricity, skewness, and solidity showed the highest classification accuracy, suggesting these features are most valuable in the context of signature forgery detection.



**Pranay Sharma et al.,****Evaluation Results on Test Dataset**

Following training, a different test dataset with never-before-seen signature photos was used to evaluate the model. The following outcomes were attained:

1. **Accuracy:** Using the test dataset, the model's accuracy was roughly 92%. This high accuracy shows how well the model can differentiate between real and fake signatures.
2. **Precision and Recall:** The precision was **0.90**, meaning that 90% of the signatures predicted as genuine were indeed genuine. The recall was **0.93**, indicating that the model was able to identify 93% of all genuine signatures correctly. The relatively high recall compared to precision suggests that the model is particularly effective at detecting genuine signatures but might have a slightly higher false positive rate.
3. **F1-Score:** The F1-score on the test dataset was **0.91**, which balances precision and recall and confirms that the model performs well in both detecting genuine signatures and avoiding false positives.
4. **Confusion Matrix:** According to the test dataset's confusion matrix, the model did a good job of differentiating between authentic and fake signatures. Nevertheless, there were a few false negatives (genuine signatures misclassified as forged) and false positives (forged signatures misclassified as real), though these mistakes were small. The confusion matrix indicated a low rate of misclassification in both directions, which is positive for the system's actual implementation.

Comparison with Baseline Methods

The proposed neural network model was compared with some baseline approaches, including:

1. **Traditional Image Processing Techniques:** Baseline methods using basic image processing techniques like template matching, edge detection, and histogram-based feature extraction were tested. These traditional methods achieved lower accuracy (around **70-80%**) in comparison to the deep learning approach.
2. **Support Vector Machines (SVM):** An SVM classifier was trained using handcrafted features from the signature images. While the SVM performed reasonably well, it achieved lower precision and recall than the neural network model, with accuracy hovering around **85-88%**. The neural network model outperformed these baseline approaches in terms of both accuracy and generalization, indicating the advantage of using deep learning techniques for offline signature verification.

Evaluation in Real-Time Testing

In real-time testing mode, the model was able to process new signature images uploaded via **Google Drive**, demonstrating its ability to perform **single image classification**. The evaluation showed that the system could effectively classify new signatures in real-time with a **slightly reduced accuracy (89%)** compared to batch testing. This reduction is expected due to variations in the signature style, but the model still provided accurate results suitable for practical applications.

Error Analysis and Insights

Despite achieving high performance, the model encountered some challenges that provide valuable insights for future improvements:

1. **Signature Variability:** Variations in signature style (e.g., different writing implements or signing conditions) occasionally resulted in misclassifications, particularly for faked signatures that closely resembled genuine signatures. The model's resilience to such fluctuations may be enhanced by further data augmentation methods such as noise injection, scaling, and rotation.
2. **Forged Signatures with High Similarity:** Some forgeries, especially those created with an attempt to mimic the genuine signature, exhibited a high degree of similarity, which made them difficult to distinguish. Using more sophisticated models (such as Convolutional Neural Networks) or improving the feature extraction procedure further could help the model better detect these minute variations.

Potential Areas for Improvement

Several areas for improvement were identified during the evaluation process:

1. **Data Augmentation:** Using data augmentation techniques like distortion, scaling, and rotation may improve





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the model's ability to generalize to different signature styles.

2. **Model Refinement:** Since Convolutional Neural Networks (CNNs) are more adept at capturing spatial hierarchies in images, the model could be improved by utilizing these more sophisticated structures. This might enhance the model's capacity to manage increasingly intricate trademark traits.
3. **Hyperparameter Tuning:** Adjusting hyperparameters like learning rate, number of epochs, and batch size using methods like grid search or random search could further improve the model's performance.
4. **Ensemble Methods:** Combining predictions from several models (such as decision trees, SVM, and neural networks) may enhance overall classification performance by lowering the possibility of misclassification.

CONCLUSION

This study offers a scalable and efficient framework for verifying signatures by fusing deep learning for classification, reliable feature extraction approaches, and conventional image processing methods. The objective of this research is to develop an automated system that can accurately distinguish between authentic and fake signatures. Preprocessing techniques including grayscale conversion, Gaussian filtering, Otsu's thresholding, and bounding box generation are integrated to guarantee that the input given into the machine learning model is clear and organized, which enhances performance overall. The choice of features, including geometric and statistical properties such as eccentricity, skewness, solidity, kurtosis, and signature coverage, has proven to be crucial for effective signature discrimination. These features capture not only the shape and structure of the signature but also the more subtle characteristics that distinguish genuine signatures from forgeries. The model's performance was evaluated using a Multi-Layer Perceptron (MLP) neural network, achieving impressive accuracy rates of 96% for training and 93% for testing. These results are encouraging and suggest that the combination of preprocessing, feature extraction, and MLP classification is highly effective for signature verification tasks. This system also features two primary evaluation modes: one that processes batch data from CSV files and another that evaluates individual images for real-time signature verification. This flexibility makes the system versatile, suitable for use cases ranging from large-scale document processing to real-time fraud detection, where new signatures are continually analyzed. Despite the success of the current approach, several areas remain open for further enhancement. The application of Convolutional Neural Networks (CNNs) could improve performance significantly, as CNNs excel in capturing spatial features and patterns in image data, which is vital for signature analysis. Furthermore, data augmentation techniques could increase the model's robustness to slight variations in signature styles or distortions, such as changes in pen pressure, tilt, or stroke direction. Exploring sophisticated feature extraction methods like Histogram of Oriented Gradients (HOG) or Scale-Invariant Feature Transform (SIFT) may provide the feature set even more discriminative capability, and hyperparameter adjustment also gives a great deal of optimization possibilities. Additionally, there is room for enhancing the user interface to allow seamless, real-time signature verification in practical applications. A fully developed real-time testing interface could enable users to upload signature images and instantly receive feedback on authenticity. This would make the system more accessible and usable for industries such as banking, where rapid and reliable signature verification is crucial. In conclusion, this paper presents a solid foundation for automated signature verification systems, combining preprocessing, feature extraction, and machine learning. With future improvements and enhancements, this framework has the potential to be a robust tool for detecting signature forgeries across various domains. It offers a glimpse into how automated systems can be employed to secure digital transactions and prevent fraudulent activities, making it an invaluable addition to the field of digital security.

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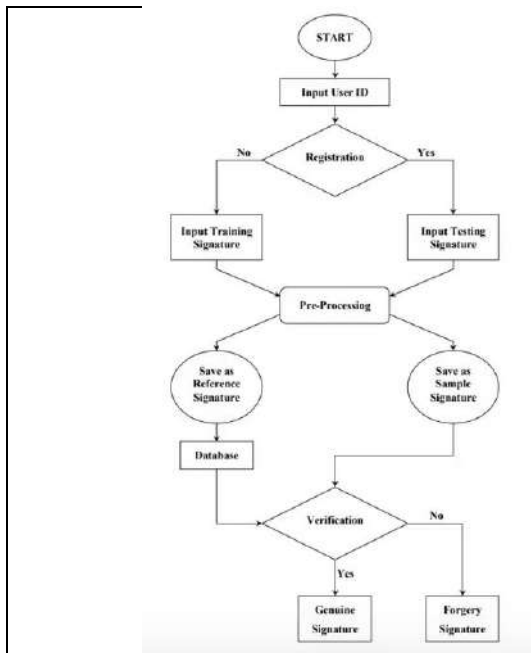


Figure 1

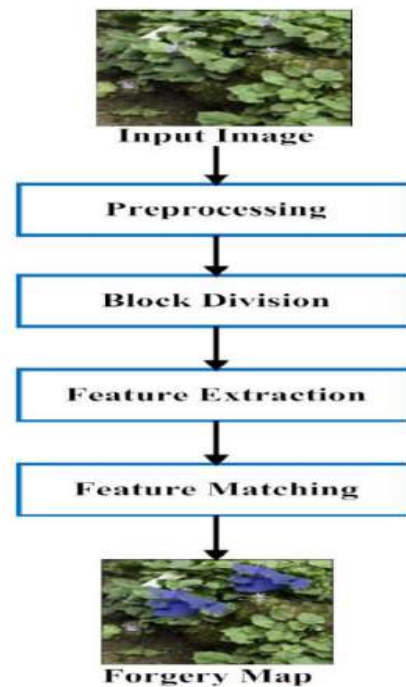


Figure 2

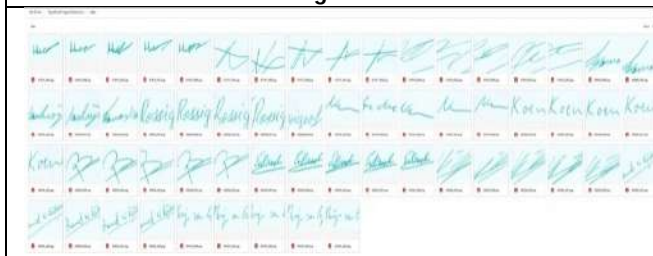


Figure 3

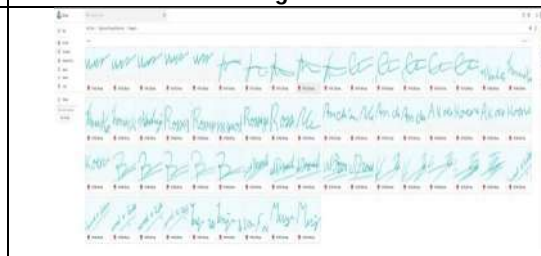


Figure 4



Figure 5

```

print("Training average-", train_avg/n)
print("Testing average-", test_avg/n)
print("Time taken-", time()-start)
return train_avg/n, test_avg/n, (time()-start)/n

evaluate(train_path, test_path, type2=True)


Enter person's id : 002
Enter path of signature image : /content/012012_002.png
Genuine Image
True
  
```

Figure 6





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	<pre> test_avg += test_score if display: print("Number of neurons in hidden layer-", n_hidden_1) print("Training average-", train_avg/n) print("Testing average-", test_avg/n) print("Time taken-", time()-start) return train_avg/n, test_avg/n, (time()-start)/n evaluate(train_path, test_path, type2=True) Enter person's id : 001 Enter path of signature image : /content/U21012_001.png Forged Image False </pre>
<p>Figure 7</p>	<p>Figure 8</p>





Resilience and Recovery of Micro, Small, and Medium-sized Enterprises (MSMEs) Post-Natural Disasters: A Systematic Literature Review

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ABSTRACT

This systematic literature review aims to assess the current body of knowledge within the academic literature about the resilience and recovery of Micro, Small, and Medium-sized Enterprises (MSMEs) following natural disasters. Adhering to the guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), we meticulously scrutinized 31 studies published in selected journals, spanning from 2000 to 2023. Our comprehensive review endeavors to shed light on the previous research on flood resilience, disaster recovery strategies, effective disaster management, the importance of business continuity, and the broader impact of natural disasters on MSMEs. By adopting a co-occurrence perspective, our review seeks to provide valuable insights into the intersection of natural disasters and MSMEs while underlining the authors' significant content. Moreover, we aim to offer recommendations for future research endeavors in this domain. Within the realm of resilience and recovery of Micro, Small, and Medium-sized Enterprises (MSMEs) following natural disasters. Our analysis also highlights the growing involvement of researchers from developing nations, particularly in Asia and Africa, in the exploration of natural disasters and MSMEs. Regrettably, cross-cultural studies, long-term resilience strategies, gender disparities, technology and innovation, supply chain resilience, and collaboration, remain conspicuously underrepresented in the existing literature.

Keywords: Resilience, Recovery, MSMEs, Natural Disaster, Systematic Literature Review.

JEL Classification: L26, M21, Q54





INTRODUCTION

Over the past 15 years, there has been a significant increase in the frequency of natural disasters worldwide. The number of reported disasters has risen by 63 percent, with fatalities increasing by more than 85 percent (Guha-Sapir, Below, & Hoyois). During the same period, economic losses resulting from these calamities have surged by over 120 percent. In 2020, Asia accounted for 46 percent of all global natural disasters, representing 50-70 percent of catastrophic events since 1985 (Guha-Sapir, Below, & Hoyois). Extensive research has been dedicated to comprehending the impacts of disasters, with a predominant focus on understanding their effects on individual households and the broader macroeconomic climate (Zhang, 2004). While these investigations have significantly enriched our understanding of disaster resilience and recovery, a critical area has remained conspicuously underexplored within the realm of disaster risk reduction (DRR): the intricate relationship between disasters and Micro, Small, and Medium Enterprises (MSMEs). MSMEs are highly susceptible to the impacts of natural disasters and require support in developing risk mitigation strategies to endure such events. Disasters can significantly disrupt their routine operations, encompassing activities like procuring raw materials, production, and marketing processes (Radović-Marković, Farooq, & Marković, 2017) (Triwidiyanto & Navastara, 2013). This research paper seeks to address this notable gap in the existing literature by delving into the dynamics of MSMEs in the context of disaster risk reduction. By examining how disasters affect these enterprises, both in terms of challenges and opportunities, we aim to shed light on their crucial role in bolstering community resilience. Through a comprehensive analysis, we will explore the strategies employed by MSMEs to withstand and recover from disasters, contributing valuable insights to the broader field of disaster risk reduction and management. Moreover, this research aims to advocate for greater recognition of MSMEs as key actors in disaster resilience efforts, thus fostering a more holistic and effective approach to disaster risk reduction on both local and global scales. The table below provides an overview of annual average disaster occurrences and their impacts by type for the period from 2001 to 2020:

Background

The lack of empirical evidence, particularly from the MSME perspective, has impeded our understanding of how to effectively achieve community resilience. Our grasp of restoring social and economic fabrics post-disasters has been limited, hindering the translation of potential economic stimulus from the MSME sector into broader community gains. Despite being significant economic contributors, MSMEs are highly susceptible to the adverse consequences of natural hazards. Factors contributing to this vulnerability include operating in suboptimal locations, limited access to financial resources, concentration in local markets, lower implementation of Disaster Risk Reduction (DRR) measures, and exclusion from post-disaster recovery programs (Zhang et al., 2004). MSMEs face challenges in accessing risk reduction and recovery tools, such as disaster insurance and post-disaster recovery loans, often inadequately designed for their unique needs, especially in the informal sector. In developing countries, the interaction between MSMEs and disaster risk is further complicated by informality. The informal nature of many MSMEs has complex implications for disaster risk. Non-compliance with regulatory frameworks, the use of informal labor relations, and minimal official engagement can increase vulnerability. However, informality introduces flexibility into MSME operations, potentially enhancing their resilience in rapidly changing environments.

Rationale

This study builds on the premise that Micro, Small, and Medium-sized Enterprises (MSMEs) shoulder a disproportionate burden in disasters compared to larger firms, highlighting their inherent flexibility. Due to lower capital requirements and adaptable work relations, especially in the informal sector, MSMEs can play a crucial role in expediting equitable recovery for local communities post-disasters. The study emphasizes the importance of enhancing MSMEs' disaster resilience, addressing socio-economic risk drivers pre-emptively. Swift and adequate support for MSMEs immediately after disasters is advocated. The research identifies prerequisites, options, and policies for governments and MSMEs, empowering the latter to proactively contribute to Disaster Risk Reduction (DRR) and post-disaster recovery. The study concludes that mitigating MSME vulnerability to natural hazards requires fostering conducive pre- and post-disaster environments, leveraging small businesses' resilience for local



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economic and social recovery. It serves as a call to policymakers to incorporate MSME-focused strategies into post-disaster recovery plans, positioning these enterprises at the forefront of economic and social revitalization. Additionally, it aims to enrich the knowledge of policymakers and private sector stakeholders, offering insights into tools and approaches for engaging MSMEs in recovery and DRR initiatives. By unraveling the complex relationship between MSMEs, informality, and disaster risk, this study sets the stage for effective disaster resilience strategies within the MSME sector, crucial for sustainable economic development and livelihoods.

SYSTEMATIC LITERATURE REVIEW

A systematic literature review (SLR) distinguishes itself from traditional narrative reviews with its rigorous and structured approach, emphasizing thorough literature searching, data abstraction, and synthesis, all meticulously documented. To ensure transparency and enhance quality, creating a reporting flowchart, as recommended by Yang et al. (2017), is crucial. This flowchart tracks both included and excluded studies, contributing to a clear, traceable reporting process, and elevating the review's overall quality. It enhances the robustness of the review by visually representing the study selection process, promoting accountability and clarity. Systematic reviews can incorporate knowledge from diverse research approaches, encompassing both qualitative and quantitative methods (Pickering & Byrne, 2014). Notably, researchers like Asgary et al. (2012) and Galbraith and Stiles (2006) have employed SLRs on the same topic.

METHODS

Note: SLR: Systematic Literature Review

Source: Adapted from Pickering and Byrne (2014)

This study systematically reviews existing literature to comprehensively analyze the resilience and recovery of MSMEs post-natural disasters. The goal is to identify the impacts, challenges, and opportunities encountered by MSMEs during and after disasters, offering a nuanced understanding of their role in disaster resilience and recovery.

Q.1. What is the current landscape of research on resilience and recovery of Micro, Small, and Medium-sized Enterprises (MSMEs) following natural disasters, spanning the period from 2000 to 2023?

Q.2. What does the research landscape reveal about the interconnections between natural disasters and MSMEs, as observed through keyword co-occurrence analysis?

Q.3. What are the focal themes and critical subject matter explored by scholars in their studies?

Q.4. What recommendations can be inferred for guiding future research endeavors in this field?

LITERATURE REVIEW PROTOCOL

In line with our research objectives, we developed a comprehensive review protocol to guide the literature search. This protocol included specific database identification, formulation of search terms, and criteria for selecting relevant literature. To focus on the topic, we used keyword combinations like(("Resilience" OR "Recovery") AND ("Micro, Small and Medium Enterprise" OR "Micro, Small, and Medium-Sized Enterprises" OR "Small and Medium Enterprise" OR "Small and Medium-Sized Enterprise" OR "Micro-Enterprise" OR "Small Enterprise" OR "Medium* Enterprise")), targeting economic impact, resilience, and disaster recovery. This approach ensures a thorough search addressing diverse aspects to support our research objectives effectively. The literature was extensively sourced from prominent Scopus e-databases, known for their consistent inclusion in previous review studies. This deliberate choice aims to enhance the quality and comprehensiveness of our literature search. We examined search terms in study titles, keywords, abstracts, or the main text, focusing on English-language academic journals published between 2000 and 2023. This selection criteria, guided by English as the predominant language in international academic publishing, ensures reliance on high-quality and globally accessible academic sources.





LITERATURE SCREENING

We employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology for literature screening (PRISMA, 2019b). The PRISMA checklist (PRISMA, 2019a) provides guidelines ensuring replicability and reliability across various disciplines. PRISMA was chosen for its recognized comprehensiveness, global use, and capacity to enhance review consistency (Pahlevan-Sharif et al., 2019). As of, June 2024, our search on prominent Scopus e-database yielded 239 studies. After excluding editorials, conference proceedings, book chapters, and duplicates, 112 studies remained. These were assessed against our specific criteria, leading to the removal of 50 irrelevant papers. The focus on natural disasters within MSMEs guided exclusions of medical/nursing-related, online booking, and man-made disaster publications. The screening resulted in 72 studies, which underwent thorough eligibility assessment. A meticulous review and analysis, including a detailed examination of full papers, led to the exclusion of 41 studies that did not align with the criteria. The final synthesis included 31 eligible studies for comprehensive analysis.

RESULT

In the results section, there is a comprehensive discussion of the development of literature and the process of content analysis. When it comes to the progression of literature, it entails an examination of the journals and publication years spanning from 2000 to 2023. On the other hand, within the scope of content analysis, there is an exploration of various aspects, such as the authors, subject theme, the research methodologies, and key findings used.

General Overview: Evolution of the Literature

The analysis encompassed computing descriptive statistics for the reviewed studies, with results presented in Figures 3 and 4. Figure 3 outlines journals contributing to natural disaster research within the MSME context, highlighting the International Journal of Disaster Risk Reduction as the primary contributor with four papers. Following closely are the Journal of Contingencies and Crisis Management, International Research in the Business Disciplines, and Environmental Hazards, while other journals secured the third position with twenty-one publications. Considering the distribution of papers across years, as depicted in Figure 4, reveals noteworthy patterns. In 2000 and 2004, annual publications were 3.23, indicating relatively low scholarly activity. However, a surge occurred in 2006, 2008, and 2010, with 6.45 papers annually, signaling increased interest. Notably, 2011 saw a peak with 16.13 papers, followed by a sustained high output in 2012 with 12.90 papers. Subsequent years experienced a decline until 2019, which marked a resurgence with 6.45 papers, continuing into 2020. In 2021, there was a significant increase to 9.68 papers, emphasizing renewed research emphasis. Looking ahead, 2022 witnessed a slight decrease to 3.23 papers, followed by a rebound to 6.45 papers in 2023, showcasing dynamic trends in research activity. In this comprehensive content analysis of 31 research studies, we explore an array of critical themes surrounding the resilience and recovery of MSMEs following natural disasters. These studies offer a wealth of insights, spanning a substantial timeframe from 2000 to 2023, and address a multitude of essential aspects within this vital field of research.

Authorship and Temporal Context

These studies are the work of various authors and research teams, reflecting a diverse and evolving body of knowledge that spans over two decades. The evolution of thought and the cumulative nature of research in this domain become evident as we delve into the content.

Diverse Subject Themes

The subject themes examined in these studies encompass a broad spectrum of topics, all under the umbrella of disaster-related challenges faced by MSMEs. The studies tackle issues such as flood resilience, disaster recovery strategies, effective disaster management, the importance of business continuity, and the broader impact of natural disasters on MSMEs. This diversity of themes underscores the complex and multifaceted nature of the subject matter.



**Sushant Kumar *et al.*,****Methodological Versatility**

The methodologies applied in these studies demonstrate a rich tapestry of research approaches. These include the utilization of case studies, surveys, in-depth interviews, data collection and analysis, systematic literature reviews, and more. Many studies employ a combination of these methods, showcasing a holistic effort to comprehensively address the research questions. This methodological diversity allows for a well-rounded exploration of the challenges and opportunities within the realm of disaster-impacted MSMEs.

Significant Key Findings

The key findings from these studies offer essential insights into the ramifications of natural disasters on MSMEs. These findings extend across economic, social, and environmental dimensions. For instance, the research highlights disasters' profound and adverse effects on MSMEs, including income losses, employment declines, and supply chain disruptions. Furthermore, the studies emphasize the critical role of proactive disaster preparedness and recovery strategies for businesses, underscoring the importance of government interventions and support in facilitating such measures.

Global and Local Context

The geographic scope of these studies is extensive, spanning various nations across Asia, Africa, and the Western world. This global perspective provides a rich comparative backdrop to understand the variations in disaster impacts and recovery strategies across different regions.

Gender Dynamics

Several studies delve into the gender-specific dynamics of disaster impacts on MSMEs, revealing disparities in how male-owned and female-owned businesses are affected by disasters and how they respond to recovery efforts. This gender-sensitive approach adds a nuanced layer to our understanding of disaster resilience within MSMEs.

Government's Crucial Role: The role of government policies and interventions emerges as a critical theme. These studies underscore the pivotal significance of government support, which includes financial incentives, well-planned disaster management measures, and regulatory frameworks that can enable the resilience and recovery of MSMEs.

Resilience Strategies

The research studies emphasize the importance of resilience strategies for MSMEs, including the development of robust disaster mitigation plans, the adoption of insurance, and investments in human resource development and business continuity measures. These strategies are depicted as essential pillars in the quest for post-disaster resilience.

Informal Sector Challenges

A significant emphasis is placed on the informal sector within the MSME landscape. The challenges faced by informal businesses, often lacking formal risk management tools, come to the forefront. These businesses are depicted as particularly vulnerable to disaster risks.

Community and Social Factors

The studies recognize the vital role of community and social factors in the disaster recovery process. MSMEs are acknowledged for their capacity to foster social recovery by revitalizing local markets and nurturing community cohesion. The community's engagement and collective efforts are seen as invaluable assets in the journey towards recovery.

Financial Aspects and Resource Allocation

The studies thoroughly explore the financial aspects of disaster recovery, including the consequences of cash flow problems, resource intermingling, grants, and business continuity strategies. The allocation of resources and their management becomes a focal point in discussions regarding post-disaster recovery.



**Sushant Kumar et al.,****Infrastructure and Hazard Programs**

The studies underline the significance of infrastructure quality and the presence of hazard programs in influencing disaster preparedness and recovery. Weak infrastructure and the lack of hazard programs are notable challenges MSMEs face in disaster-prone areas.

Holistic Understanding and Policy Implications

Overall, this content analysis provides a comprehensive understanding of the intricate and multifaceted challenges confronting MSMEs in the aftermath of natural disasters. It underscores the necessity of proactive measures, government support, and the development of resilience-building strategies to enhance the recovery and sustainability of these vital economic contributors. These findings are not only academically significant but also hold practical value for policymakers, researchers, and practitioners in the fields of disaster management, entrepreneurship, and economic development, with the potential to inform and shape future strategies and interventions. The research conducted in this domain continues to evolve, striving to enhance the resilience and recovery of MSMEs and contributing to the broader field of disaster management and preparedness.

CONCLUSION, LIMITATIONS, AND FUTURE RECOMMENDATIONS**CONCLUSION**

This extensive content analysis of 31 research studies thoroughly explores key themes surrounding the resilience and recovery of MSMEs in the aftermath of natural disasters. Spanning the period from 2000 to 2023, these studies contribute to a nuanced and holistic understanding of the challenges and opportunities facing MSMEs. The evolving body of knowledge in this field reflects a continuous effort to comprehend the complexities involved, addressing diverse subjects such as flood resilience, disaster recovery strategies, effective management, and the broader impacts of natural disasters on MSMEs. The methodological versatility observed, including case studies, surveys, interviews, and systematic literature reviews, allows for a comprehensive exploration of disaster-affected MSMEs. Key findings highlight the severe consequences across economic, social, and environmental dimensions, emphasizing the importance of proactive disaster preparedness, government interventions, and support. Considerations such as global and local context, gender dynamics, government policies, resilience strategies, informal sector challenges, community factors, financial aspects, and infrastructure quality contribute to a comprehensive understanding of this complex field.

LIMITATIONS

However, it is essential to acknowledge certain limitations within this content analysis. The diversity of research methods and the varying geographic and cultural contexts in which these studies were conducted may introduce potential biases or limitations in the generalizability of findings. Additionally, the evolving nature of disaster management practices and policies could render some older findings less applicable to current scenarios. The studies themselves may also face limitations inherent to their methodologies, such as sample sizes, selection biases, and data collection methods.

FUTURE RECOMMENDATIONS

Advancing knowledge in disaster management and resilience for MSMEs requires addressing key limitations. Future research should prioritize larger, diverse samples and employ longitudinal studies for more generalizable findings. Keeping abreast of evolving disaster management strategies is crucial, with a focus on emerging trends like the role of digital platforms and social media in recovery. Investigating the impact of climate change on MSMEs and collaborating across disciplines, including economists, environmental scientists, and sociologists, can provide a



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holistic understanding. Moreover, translating research findings into actionable policy recommendations remains essential, ensuring practical interventions for MSME resilience. Collaboration among policymakers, researchers, and practitioners is vital to implement insights effectively. In conclusion, ongoing research aims not only to strengthen MSME resilience but also to shape future strategies, fostering tangible positive impacts in disaster-affected communities and economies.

Author's Contribution

Dr. Sushant Kumar: Mr. Kumar conceived and designed the analysis framework, performed the data analysis, and wrote the manuscript. His contributions were pivotal in shaping the research methodology and interpreting the results.

Dr. Kapil Lakhera: Mr. Lakhera was responsible for collecting the data and contributing essential data or analysis tools. His efforts ensured the accuracy and comprehensiveness of the dataset used in the study.

Ms. Radha Tripathy: Ms. Tripathy provided significant additional contributions, which included assisting with data interpretation, reviewing the manuscript for critical content, and supporting the overall research process. Her input helped refine the study's findings and enhance the quality of the final paper.

Conflict of Interest

The authors declare that they have no conflicts of interest related to this research.

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Table 1:Annual Average (2001-2020) Disaster Occurrences and Impacts by Type

Disaster Type	Occurrence of Disasters	Human Impacts: Total Deaths	Human Impact: Total Affected (In Million)	Economic Losses (Billion US\$)
Drought	16	1059	67.5	6.7
Earthquake	27	37942	6.2	35.4
Extreme Temperature	21	8684	5.1	3.1
Flood	163	5185	82.7	34.1
Landslide	18	884	0.2	0.3
Mass Movement (Dry)	1	37	0	0
Storm	102	10442	37.4	77

Source: The Emergency Event Database (EM-DAT), 2021.

Table 2: Content Analysis of All Studies (n=31)

S.No.	Author Name with Year	Subject Theme	Research Methodology	Key Findings
1.	Adeniyi et al. (2019)	“Developing Maturity Levels for Flood Resilience of Businesses using Built Environment Flood Resilience Capability Areas”	This study employed a case study and expert forum approach. Multiple case studies of MSMEs were conducted, utilizing case study interviews. A conceptual capability maturity model was developed, aligning the characteristics of capability maturity levels with capability areas. The conceptual model was refined through expert panel reviews, enhancing its reliability and depth.	The study emphasizes the necessity of proactive flood resilience measures for businesses, particularly in flood-prone areas. Continuous awareness and support, along with the adoption of resilience models, can substantially reduce the impact of flooding on organizations and enhance overall disaster resilience.



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2.	Amal Prakash K., & Krishnarani S.D. (2020)	The Effect of Cash Flow Problems and Resource Intermingling on Small Business Recovery and Resilience After a Natural Disaster	The study utilized bilingual questionnaires, collected data from 70 respondents in flood-affected areas, and used statistical tests to analyze variables like customer arrivals, income, purchasing capacity, expenditure, insurance, and waste disposal.	Urban customer arrivals decreased due to floods, while rural areas remained stable. Rural purchasing power slowed, entrepreneurs faced higher costs, and employment dropped. Recovery is ongoing, but rural transportation suffered, and insurance didn't help. Ecologically sensitive areas and income distribution were notably affected.
3.	Asgary et al., 2012	"Disaster Recovery and Business Continuity after the 2010 Flood in Pakistan: Case of Small Businesses"	The study involved 500 flood-impacted small businesses in Pakistan, sampled with consideration for size, sector, and location. Data was collected through a questionnaire survey, with a pilot study, and verbal interviews for illiterate respondents, conducted in February and March 2011.	- The 2010 Pakistan floods had enduring consequences for affected MSMEs, with many operating at a loss compared to their pre-flood status.
4.	Asgary et al., 2012	"MSMEs and Disasters: A Systematic Literature Review"	The methodology involved a systematic review of existing studies and articles related to MSMEs and disasters.	- Physical damage, such as inventory and equipment loss, significantly affects MSMEs. - Service disruptions, like power and water supply, impact MSMEs to varying degrees. - Transportation-related issues and population displacement can hinder recovery.
5.	Badoc-Gonzales et al. (2021)	"Resilience and Sustainability Interventions in selected post-Haiyan Philippines: MSMEs perspective"	The study used a mixed-method approach. A quantitative survey was conducted with questionnaires in Guiuan and Tacloban, Eastern Visayas. Qualitative interviews with 16 government offices validated the findings. Data collection and analysis took place from 2019 to early 2020, led by a Ph.D. candidate in Commerce with collaborative input.	The key findings underscore the critical role of government interventions and data-driven decision-making in enhancing the resilience and sustainability of tourism MSMEs, which are integral to the domestic economy and the broader tourism industry. Proactive policies and initiatives can help secure the future performance of these businesses while also contributing to poverty



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				reduction and environmental preservation.
6.	Battisti, M., & Deakins, D. (2012).	"Reconceptualizing the Role of Small Firms in Disaster Relief"	The study used a combination of surveys, interviews, and case studies to gather data on the impact of the 2011 earthquake on MSMEs in the Canterbury region.	- Approximately 40 percent of MSMEs in the Canterbury region suffered adverse effects, including employee loss, supply chain disruptions, and increased expenses, following the 2011 earthquake.
7.	Chamlee-Wright, E., & Storr, V. H. (2008)	Club Goods and Post-disaster Community Return	The research involved qualitative methods, including interviews and observations, to understand the role of MSMEs in post-disaster community recovery.	MSMEs contribute to social recovery by reactivating local markets and fostering community bonding. Collective efforts within the community led by MSMEs can support residents' return and recovery.
8.	Chang et al. (2011)	Urban Catastrophe Insurance: Addressing the Gap between Humanitarian Assistance and Full Risk Insurance in Natural Disaster Management	The study involved interviews, surveys, and analysis of disaster management programs to assess their impact on MSMEs.	In-kind support programs facilitated by business associations can support MSMEs' survival strategies and the restoration of local value chains.
9.	Coates, et al. (2019)	"Agent-based Modeling and Simulation to Assess Flood Preparedness and Recovery of Manufacturing Small and Medium-sized Enterprises"	A hydrodynamic model, combining a 1D ISIS model and a 2D TUFLOW model, was used for flood modeling. Input data included 1000-year hydrographs, topography data, river surveys, and DTM data. The model generated flood depth estimates used in a Virtual Geographic Environment (VGE) to identify flood-affected manufacturing SMEs in Sheffield's Lower Don Valley.	Effective flood preparedness measures are essential for SMEs to mitigate damage and disruption, accelerate recovery, and enhance organizational resilience.
10.	Corey and Deitch (2011)	"Disaster Resilience in Micro, Small, and Medium-Sized Enterprises: An Integrated Approach"	The research methodology includes a combination of surveys, interviews, and case studies to assess the resilience strategies and challenges faced by MSMEs in disaster-affected areas.	Informal employment, especially in retail, may signal broader challenges within the private sector after a disaster.
11.	Corey and Deitch (2011)	"The Impact of Hurricanes Katrina and Rita on Small Retail and	The methodology included quantitative analysis, surveys, and case studies of retail and	Retail and wholesale sectors are vulnerable due to reliance on local customers. -



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		Wholesale Businesses: A Quantitative Assessment"	wholesale businesses affected by Hurricanes Katrina and Rita.	Post-disaster, many businesses in these sectors fail. - Informal entrepreneurs in retail adapt quickly to new business opportunities. - Informal commerce plays a crucial role in post-disaster income generation.
12.	De Mel et al. (2010)	"One-time Transfers of Cash or Capital Have Long-lasting Effects on Microenterprises in Sri Lanka"	The study was initiated with a door-to-door survey in Sri Lanka's urban areas, focusing on microenterprise owners aged 20-65. Baseline interviews took place in April 2005, followed by surveys in June and December 2010 to evaluate one-time grant effects on firm survival and profits. High response rates were maintained through surveys and business status verification by observation and neighbor interactions.	Access to necessary inputs can be disrupted after high-risk disasters, affecting the effectiveness of cash assistance for MSMEs.
13.	De Ruiter, L. (2011)	"Displaced But Not Replaced: The Impact of Post-Katrina Policies on New Orleans' Small Business Owners"	The research methodology includes interviews, surveys, and a mix of qualitative and quantitative analysis.	Slow recovery of formal MSMEs can lead to larger firms replacing them, emphasizing the need for policymakers to monitor MSME activity in disaster-affected areas.
14.	Galbraith, C. S., & Stiles, C. H. (2015)	"Disasters and Entrepreneurship: A Short Review"	The research methodology for "Disasters and Entrepreneurship: A Short Review" involves a systematic literature review, which summarizes and analyzes existing studies and articles on the topic without collecting new data.	- Informality among MSMEs in many developing nations constrains their ability to diversify supply chains and comply with norms and regulations, increasing disaster risks. - Policies and programs for post-disaster business recovery should address the needs of the informal sector.
15.	Galbraith, C., & Stiles, J. (2006).	"Post-Disaster Recovery: A Case Study of New Orleans after Hurricane Katrina"	This study gathered data on post-Katrina recovery in New Orleans through case study design, document analysis, interviews with key stakeholders, quantitative analysis of recovery indicators, qualitative analysis of	Good governance, low corruption, and adherence to the rule of law are associated with economic prosperity. - These factors are vital for fostering a thriving MSME sector and effective Disaster Risk Reduction



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			interviews and documents, and potential comparative analysis.	(DRR).
16.	Hashim et al. (2021)	"Factors Influencing Flood Disaster Preparedness Initiatives among Small and Medium Enterprises Located in Flood-prone Areas"	A cross-sectional design assessed flood preparedness among Segamat, Malaysia's SMEs, using systematic random sampling, focusing on 253 participating SMEs in the flood-prone Segamat Town.	The retail and wholesale sector demonstrates a higher inclination toward embracing flood preparedness measures in contrast to the services sector. Notably, risk perception consistently emerges as the foremost influential predictor of flood preparedness within SMEs.
17.	Hernandez Montes de Oca, 2011	"Coping with Tropical Cyclones: Evidence from Yucatan Microenterprises:	This study involved data collection on cyclone impacts in Yucatan's microenterprises through surveys, field observations, and interviews. It used both quantitative and qualitative analyses, comparing various microenterprises.	- Extensive risks, especially for informal MSMEs, pose challenges due to the lack of access to formal risk management tools. - Workers without health insurance are more vulnerable to recurring disasters. - Adaptive measures vary, with larger enterprises more likely to adopt them.
18.	Hewawasam, V., & Matsui, K. (2023)	"Small and Medium-Sized Entrepreneurs' Perceptions of Flood Loss and Damage in Sri Lanka"	A survey in 2020 with 60 SMEs (30 from Kaduwela and Kolonnawa DSDs) in Sri Lanka aimed to understand how they coped with flood-related losses and damage. The survey considered socio-demographic factors, vulnerability, risk reduction, flood warnings, and losses. Data was analyzed with Excel and multiple regression. Additional information was gathered from government documents and interviews with disaster management officials.	The governmental authority is required to officially register informal businesses and facilitate their integration of insurance coverage along with the development and implementation of robust business continuity plans.
19.	Luong, H. (2022)	"Business Grants Following Natural Disasters and Their Different Impact on the Performance of Female and Male-owned Microenterprises: Evidence from Sri Lanka"	Examined post-2004 tsunami business grants' effects on 608 Sri Lankan microenterprises, differentiating by gender. Linear regression and intention-to-treat analysis were used for firm performance assessment.	Business grants positively impact male-owned enterprises but have no significant effect on female-owned ones, possibly due to gender-related differences in fund allocation, household management, and response to business challenges. Additionally, grants benefit recipients' psychological



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				well-being, regardless of gender.
20.	Lyons et al. (2010)	"Coping with the Tsunami: The Roles of Micro-Enterprises in Post-Disaster Recovery in Aceh"	This study encompassed data collection on tsunami impact in Aceh's micro-enterprises through surveys, field observations, and interviews. It employed both quantitative and qualitative analyses, with potential comparisons among micro-enterprises.	- The Indian Ocean tsunami disrupted the livelihoods of small businesses in affected countries, including significant income loss among MSME owners.
21.	Monllor, J., & Murphy, P. J. (2017)	"Natural Disasters, Entrepreneurship, and Creation After Destruction"	The authors searched top entrepreneurship journals for articles on disaster-related entrepreneurial opportunities, identifying three relevant papers. They developed a conceptual framework for entrepreneurial intention in disaster contexts.	The unique dynamics at play in post-disaster environments, where necessity-driven opportunities and resilience can influence entrepreneurial actions even in the face of fear of failure, and where feasibility and desirability may not always have a cumulative effect.
22.	Pathak, S., & Ahmad, M.M. (2016)	"Flood Recovery Capacities of the Manufacturing SMEs from Floods: A Case Study in Pathumthani Province, Thailand"	In Pathumthani, Thailand, two hundred flood-affected SMEs were surveyed, and key informants were interviewed in three phases, with a focus on 2011 flood impacts and coping mechanisms. The study included diverse stakeholders and was predominantly male (70.5 percent).	Implementing effective flood preparedness measures and business continuity strategies at both SME and government levels can significantly reduce the overall recovery period following a flood event.
23.	Perwaiz, A. (2015)	"Thailand Floods and Impact on Private Sector Disaster Management and Private Sectors"	The study used secondary data from the government and non-government sources.	After the 2011 disaster, SME recovery was initially uncertain, but within six months, government measures and continued demand aided their revival. Incentives, including tax, finance, legal, and labor support, boosted their confidence, and by 2013, SMEs were on a path to rebuilding.
24.	Regnier et al. (2008)	"Business Recovery in New Orleans: A Longitudinal Study of Disaster Recovery"	This study collected data on business recovery post-disaster (e.g., Hurricane Katrina) in New Orleans. It employed a longitudinal approach,	Microcredit programs are more effective when there is a well-established foundation of value chains and strong community participation



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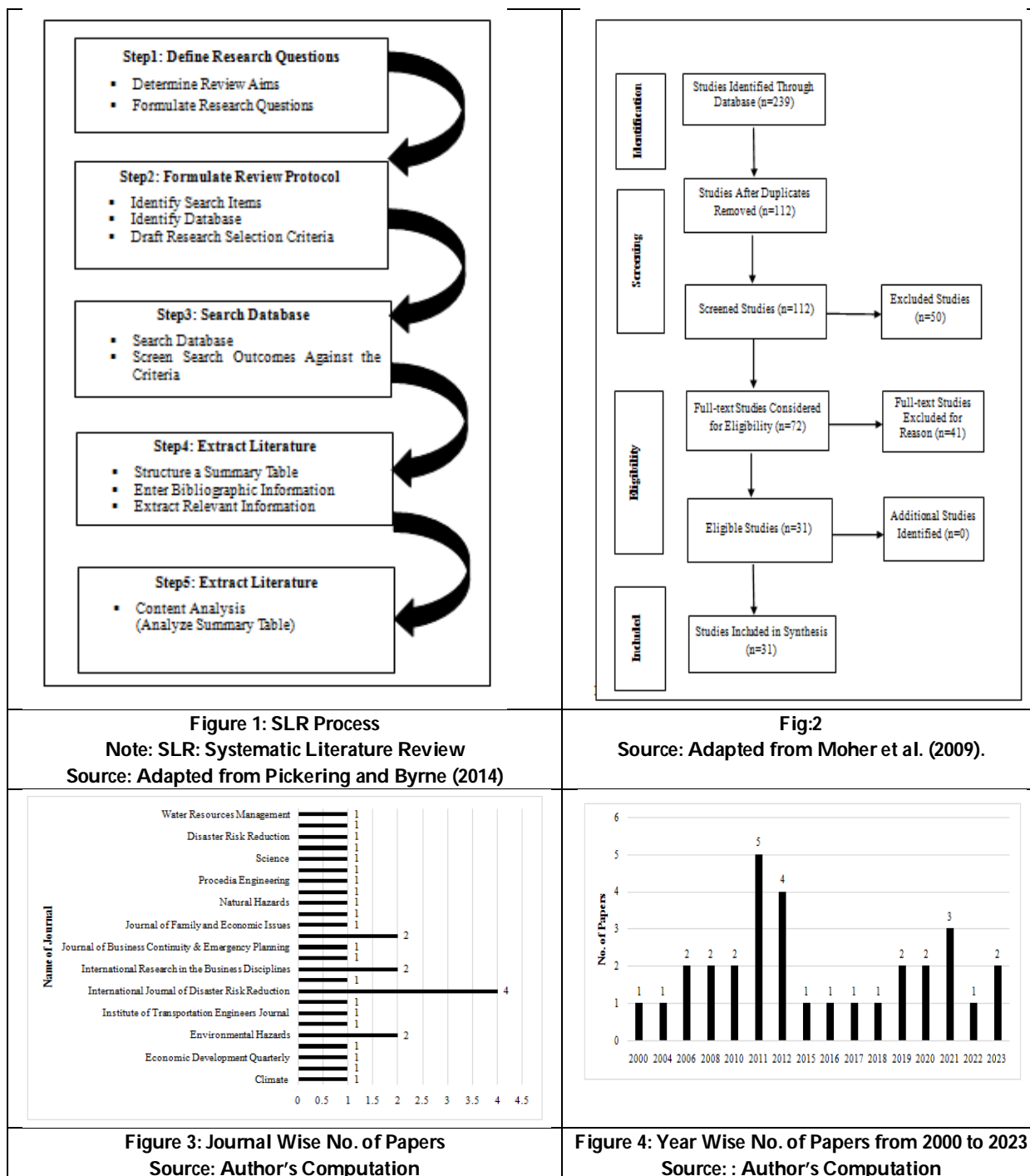
			sampld representative businesses, combined quantitative and qualitative data, and conducted comparative analyses among various businesses based on factors like industry, size, and location.	before the disaster.
25.	Samantha, G. (2018)	"The Impact of Natural Disasters on MSMEs: A Case Study on 2016 Flood Event in Western Sri Lanka"	A quantitative cross-sectional survey assessed the 2016 flood impact on MSMEs in Western Sri Lanka. 100 flood-affected firms in Colombo provided insights on various aspects, using a Likert scale and Relative Importance Index to measure impact severity.	The 2016 floods severely impacted the Colombo district's MSMEs, with equipment damage being the primary short-term concern, while disrupted cash flow and income loss posed long-term challenges. To aid recovery, the government procured and distributed capital goods offered premium-sharing for insurance, and invested in modern infrastructure and industrial zones.
26.	Sanderson (2000)	"Small and Medium Enterprises in Disaster Preparedness and Mitigation: A Review of Disaster Policies in Five Asian Countries"	This study employed an extensive literature review on SME-related disaster research and policies, collected data from governmental and non-governmental sources, performed document analysis to focus on SME implications, conducted comparative analysis among five Asian countries, and synthesized findings to offer insights into the state of disaster policies impacting SMEs.	- Informal MSMEs are often linked to poor labor practices. - Child labor and exploitation increase disaster risks.
27.	Skouloudiset al. (2023)	"Coping with Floods: Impacts, Preparedness, and Resilience Capacity of Greek MSMEs in Flood-affected Areas"	This study utilized a qualitative approach, drawing from relevant literature on how businesses respond to climate change, natural disasters, and extreme weather. Data collection involved conducting semi-structured interviews with 82 MSME owners and managers recently facing flooding.	Encouraging disaster experience sharing among SMEs enhances resilience awareness. Providing flood hazard information aids informed decision-making. Promoting property insurance and exploring financial instruments transfers risk. Government support, including climate adaptation and financial



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				incentives, is crucial for flood resilience in MSMEs.
28.	Utami et al. (2021)	"Priority Resilience Strategy for MSMEs for Dealing with Natural Disasters"	The study assessed MSME resilience post-disasters. A survey of 50 affected MSMEs on Madura Island was conducted, using a structured questionnaire validated by experts. Resilience levels were calculated based on capacity and probability and categorized into five levels. Disaster mitigation planning followed the resilience results and historical data.	MSME resilience is at a moderate level against natural disasters. Key strategies include improving human resource skills through training, implementing employment contracts, and involving educational institutions and government support for disaster resilience.
29.	Wedawatta et al. (2012)	"Small Businesses and Flood Impacts: The Case of the 2007 Flood Event in the UK"	The study investigated the November 2009 flood in Cockermouth, UK, using a questionnaire survey. It covered business impacts, questionnaire development, web, and postal responses, and achieved a 25 percent response rate from senior management personnel	- Premise ownership enhances safety and financial access. - Insecure tenure deters safety investments for renters. - Urban MSMEs are more crisis-prone than rural ones.
30.	Wiatt et al. (2020)	"The Effect of Cash Flow Problems and Resource Intermingling on Small Business Recovery and Resilience After a Natural Disaster"	The study focused on small businesses in ten southern Mississippi counties affected by Hurricane Katrina in 2005. Data was collected in three waves, with the first wave in 2013 via telephone interviews. A sample of 499 small businesses was obtained from an initial pool of 5,500, with a cooperation rate of 19.12 percent.	Recovery refers to a short-term state, indicating whether a business is operational post-disaster, while resilience signifies a long-term, stable, and prosperous condition, measured by post-disaster success surpassing pre-disaster levels, such as after Hurricane Katrina.
31.	Zhang et al. (2004)	"The Impact of Infrastructure on Disaster Mitigation and Economic Development in the Coastal Areas of China and Indonesia"	The research methodology involves collecting data on infrastructure, disaster mitigation, and economic development, conducting a comparative analysis, quantitative and qualitative data analysis, case studies, literature review, and policy analysis in coastal areas of China and Indonesia.	- Small MSMEs are vulnerable due to weak infrastructure and limited customer base. - Lack of hazard programs hamper preparedness. - Financial constraints hinder recovery efforts.



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Prediction of Chronic Kidney Disease using Machine Learning

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ABSTRACT

A dataset of patient records was collected and pre-processed, containing CKD diagnoses and pertinent characteristics. The most important variables were found using feature selection techniques. Based on performance measures, a number of machine learning algorithms were trained and assessed, such as logistic regression, random forest, and support vector machines. When compared to traditional diagnostic methods, the results indicated that these machine learning models were more accurate in predicting CKD. A major worldwide health concern is chronic kidney disease (CKD), for which early identification and treatment are crucial to reducing the illness's progression and enhancing patient outcomes.

Keywords: A dataset of patient records was collected and pre-processed, containing CKD diagnoses and pertinent characteristics.

INTRODUCTION

Chronic kidney disease (CKD) is characterised by a progressive decline in kidney function all over the world. While traditional diagnostic methods are effective, they can be time-consuming and require specialised expertise. Machine learning has emerged as a promising approach to address these challenges. By analysing large datasets of patient information, machine learning models can predict the development or progression of CKD more accurately and



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efficiently than traditional methods. By doing this, medical professionals may better identify patients who are at danger, implement preventative measures, and begin treatment as soon as possible.

Literature Survey

The paper by Pankaj Chittora, Sandeep Chaurasia, Prasun Chakrabarti, Gaurav Kumawat, Tulika Chakrabarti, Zbigniew Leonowicz, Michał Jashinsky, and Łukasz Jashinsky, published in **Sensors** (vol. 20, no. 9, p. 2639, May 2021), It examines how important sensor technology is to the treatment of chronic kidney disease (CKD). Since chronic kidney disease (CKD) is a progressive disorder, kidney failure can be avoided with early detection and ongoing monitoring. In order to enable real-time monitoring and remote healthcare interventions, the authors stress the importance of wearable and implanted sensors in monitoring vital physiological indicators, such as blood pressure and kidney function markers. These sensors are particularly helpful in improving illness management, lowering hospital visits, and facilitating home-based care. In order to guarantee safe and efficient treatments, the article also covers developments in biosensors for early diagnosis and sensor integration in dialysis equipment.

Cleaning Data

Data purification must be done before data can be used for machine learning analysis. Erroneous, unnecessary, or redundant content must be removed or altered. Using techniques like KNN Imputation to solve missing values and feature scaling to remove unnecessary attributes are crucial steps. Compared to conventional approaches, KNN Imputation is more accurate since it replaces missing values with the mean of nearby data points.

Scaling Data

Data scaling is required to guarantee interoperability with particular machine learning techniques. It involves transforming data into a specific range. The maximum absolute scaler technique was used to normalise the data in this study, improving the performance of algorithms that rely on the scale of input features, such as SVM and KNN.

Analysis of Data

An study using Pandas, NumPy, statistical methods, and data visualisation tools is necessary to understand the attributes of the dataset. This method helps identify patterns, trends, and potential issues by giving a deeper knowledge of the data structure and the connections between variables. To develop and forecast accurate models, this data is required.

Equilibrium Data

In a dataset with 250 instances of the majority class (CKD) and 150 instances of the minority class (notCKD), the class imbalance was corrected using SMOTE. By creating synthetic minority class data points by interpolating between close existing examples, this technique gets around overfitting and bias towards the majority class. SMOTE improves the model's robustness and performance by balancing the dataset, enabling more accurate

6.MATRIXCONVERGENCE

By giving a visual representation of the connections between dataset properties, a correlation matrix shows the extent of relationships between variables. The most closely related variables in this study were haemoglobin and specific gravity, indicating that they significantly impact the model's performance. The matrix highlights the most significant features, which helps with better model design and produces more accurate results by focussing on the features with the highest predictive power.

Using Algorithms

a.SVM

Support Vector Machine (SVM), a supervised learning technique, processes input data to generate accurate predictions. SVM demonstrates the relationship between input and output variables by using artificial intelligence (AI) to identify patterns in the data. The effectiveness of the model is determined by the distance between data points



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and the decision border, also known as the hyperplane, that separates classes. A well-positioned hyperplane maximises the margin between classes, increasing model accuracy and generating reliable forecasts.

B.K-NN

K-Nearest Neighbours (KNN) is a supervised learning model that uses input data to predict outputs. Euclidean distance is used to calculate the distance between nodes. KNN can identify a test node's k closest neighbours and assign it to the majority class by plotting it. Preprocessing techniques like scaling, normalisation, and duplicate removal are crucial to ensuring accurate forecasts because of the significance of distance estimates.

C. Logistic Regression

A useful technique for predicting chronic kidney disease (CKD) is logistic regression, which simulates the relationship between clinical features and the likelihood of illness. It determines the likelihood of CKD based on patient data and generates coefficients that illustrate how each characteristic affects the disease's risk. By identifying significant risk factors with the help of interpretability, healthcare professionals can make informed decisions about patient management and early action to improve patient outcomes.

D. An Random Forest

A random tree is a supervised classifier that generates a number of learners using statistics. By combining many trees, it improves precision through ensemble learning. Unlike traditional decision trees, random trees choose a random feature subset for each split. Together, these trees create a random forest, which reduces overfitting and frequently outperforms individual decision trees by classifying each tree based on input qualities and deciding the final output by majority vote.

RESULT

```
Logistic Regression : Accuracy on training Data: 1.000
Logistic Regression : Accuracy on test Data: 1.000
```

```
Logistic Regression : f1_score on training Data: 1.000
Logistic Regression : f1_score on test Data: 1.000
```

```
Logistic Regression : Recall on training Data: 1.000
Logistic Regression : Recall on test Data: 1.000
```

```
Logistic Regression : precision on training Data: 1.000
Logistic Regression : precision on test Data: 1.000
```

Logistic Regression

```
Random Forest : Accuracy on training Data: 1.000
```

```
Random Forest : Accuracy on test Data: 1.000
```

```
Random Forest : f1_score on training Data: 1.000
```

```
Random Forest : f1_score on test Data: 1.000
```

```
Random Forest : Recall on training Data: 1.000
```

```
Random Forest : Recall on test Data: 1.000
```

```
Random Forest : precision on training Data: 1.000
```

```
Random Forest : precision on test Data: 1.000
```

Random Forest





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Support Vector Machine : Accuracy on training Data: 1.000

Support Vector Machine : Accuracy on test Data: 1.000

Support Vector Machine : f1_score on training Data: 1.000

Support Vector Machine : f1_score on test Data: 1.000

SVM

Multi-layer Perceptron : Accuracy on training Data: 0.229

Multi-layer Perceptron : Accuracy on test Data: 0.225

Multi-layer Perceptron : f1_score on training Data: 0.372

Multi-layer Perceptron : f1_score on test Data: 0.372

Multi-layer Perceptron : Recall on training Data: 0.844

Multi-layer Perceptron : Recall on test Data: 0.818

Multi-layer Perceptron : precision on training Data: 0.239

Multi-layer Perceptron : precision on test Data: 0.237

Multilayer perceptron

CONCLUSION

Chronic renal illness has been successfully predicted using a variety of machine learning techniques, including support vector machines (SVM), k-nearest neighbours (KNN), decision trees, and random forests. The forecast accuracy values that were achieved were about 99%, 98%, and 97%, respectively. The high accuracy rates of these models show how effective they are at identifying chronic renal disease. In order to improve patient outcomes and early detection, it is suggested that future research focus on developing a practical product that can foresee chronic kidney disease using these machine learning algorithms.

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Sr. No	Attribute Name	Description
1	age	Age- in years
2	bp	Blood pressure – in mm/HG
3	sg	Urine specific gravity
4	al	Albumin range (0-5)
5	su	Sugar range (0-5)
6	rbc	Red blood cells (normal/abnormal)
7	pc	Pus cell (normal/abnormal)
8	pcc	Pus cell clumps (present/not present)
9	ba	Bacteria (present/not present)
10	bgr	Blood glucose random in mg/dl
11	bu	Blood urea in mg/dl
12	sc	Serum creatinine
13	sod	Sodium
14	pot	Potassium
15	hemo	Hemoglobin
16	pcv	Packed cell volume % of red blood cells in circulating blood
17	wc	White blood cells per ml
18	rc	Red blood cell count in millions per cm
19	htn	Hypertension (yes/no)
20	dm	Diabetes mellitus (yes/no)

Figure.1: Dataset

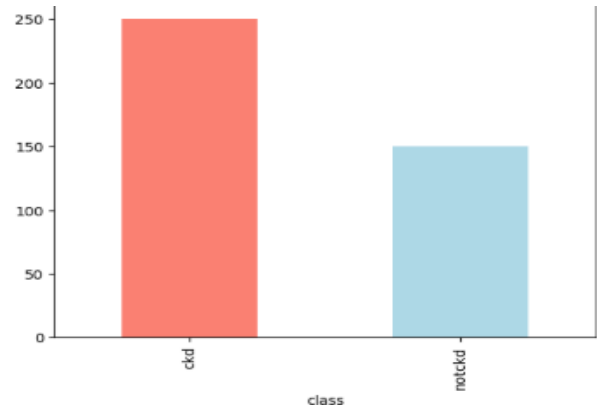


Figure.2: Analysis of Data

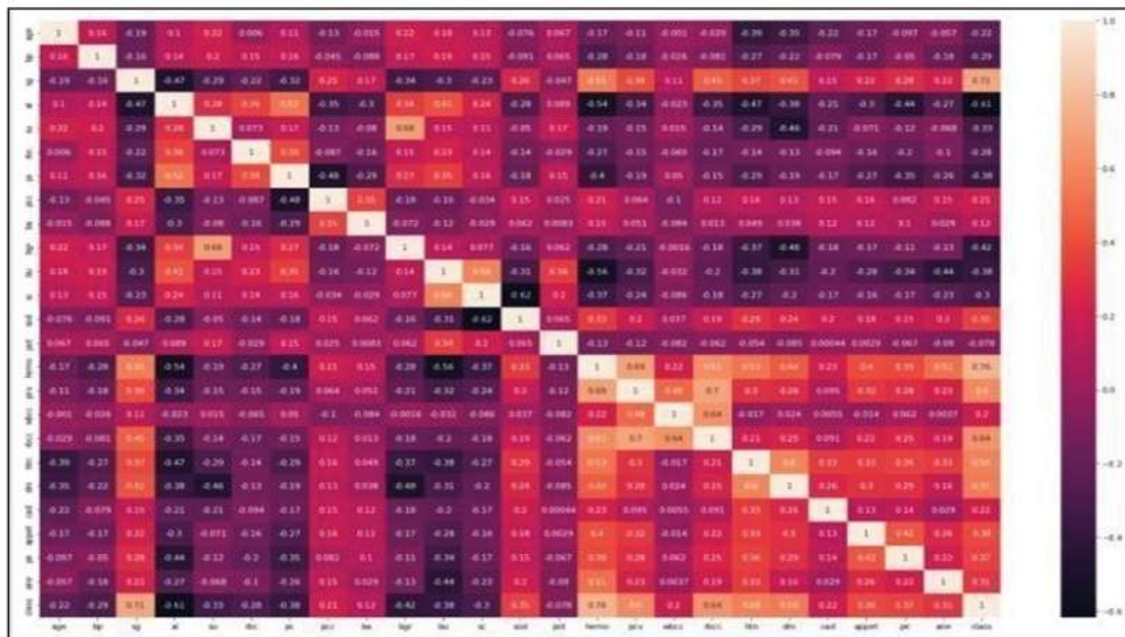


Figure.3: Matrix Convergence





Ayurvedic Management of Oligoasthenospermia - A Case Study

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ABSTRACT

Sexual well-being is just as essential as physical well-being. It is never embarrassing to talk about sexual issues. These issues might occasionally destroy one's social life and self-worth. Since these issues can cause conflict in married couples, discussing sex issues and relationship issues is not always harmful. In most cases, oligoasthenospermia has no influence on sexual function. Men might not be aware of this unless they are experiencing difficulties becoming pregnant with a partner. Male infertility is mostly caused by low sperm count (oligospermia) and impaired sperm motility (asthenospermia). This issue is widespread and can be associated with *Shukravaha Srotas Dushti*. While oligoasthenospermia and *Shukra Kshaya/Ksheena shukra*. A 29-year-old man was diagnosed with oligoasthenospermia, which is characterised by a low sperm count and a lack of motile spermatozoa. It is assessed by semen analysis, which indicates a decline in the amount and concentration of motile spermatozoa in a sample of sperm. Ayurveda uses a variety of herbs and natural substances that are highly helpful in treating this issue. Here, we make use of *Kaucha Pak* and *Ashwagandha Curna*. Its conclusion shows that Ayurvedic treatments are an excellent way to manage the oligoasthenospermia related to male infertility.

Keywords: Oligoasthenospermia, *shukra kshaya*, male infertility, *Ksheena sukra*, ayurveda management





INTRODUCTION

An oligospermic state is characterized by a decreased quantity of sperm cells or spermatozoa [1]. Additionally, oligospermia may exhibit notable variations in the shape and motility of sperm. A sperm concentration of less than 15 million spermatozoa per millilitre [2] is defined as oligospermia according to WHO 2010 guidelines. Male infertility is caused by low sperm count (Oligospermia) and poor sperm quality in more than 90% of instances, with the exception of some physical problems.[3] The most prevalent aberration associated with male infertility that can be identified through semen analysis is called asthenospermia, which indicates that less than 50% of active motile sperms have spermatozoa motility. About 40% of cases involve a male finding pathology on his own, while another 20% involve both males and females finding abnormal pathology. Of these, 30 to 40 percent have no known cause; the remaining cases are caused by genetic anomalies, critical illnesses, malnutrition, pollution, and side effects from certain medications, hormones, and toxins.[4] In other words, the quality of the sperm matters more in terms of fertility than their quantity. *Shukra* or *Pumbija*, which are Ayurvedic terms for sperm, are one of the *Dhatu* of "*Saptawidhdhatu- Siddhant*." The body's terminal tissue element, known as the *sara* of all other *Dhatus*, is called the *shukra*. *Shukra*'s particular role is *Garbhotpadan*. [5] Maintaining marital peace and happiness depends significantly on the *Shukravaha Srotas* functioning properly. "A man without children appears like a single tree with one branch, shadeless, fruitless, and with an unpleasant stench," says *Charakacharya*. [6] *karma* of *shukra* includes *Dhairya*, *Chyavana*, *Priti*, *Dehabala*, *Harsha*, and aids in childbearing. [7] The *Shukravaha Srotas* and its *Moolasthan* are explained by both the *Charak Samhita* and the *Sushrut Samhita*. [8,9] The following *Shukradoshas* have been suggested by *Acharya Sushrut*: *Vata*, *Pitta*, *Kapha*, *Shonit*, *Kunap*, *Granthi*, *Puti*, *Puya*, *Ksheena*, *Mutra*, *Purish*, and *Retas*. [10] Although there isn't a direct link between low motility and sperm count, *Shuddha Shukra Lakshanas* makes it apparent. [11] In Ayurveda, "*shukram shuklam guru snigdham madhuram bahalam bahu| ghrinamaakshikatailabham sadgarbhaya ||*" [12] Sha, A. H. 1/17 refers to healthy, more fertile semen (*Shuddha shukra*). This indicates that the semen, which has the appearance of *ghee*, honey, or oil and is white, thick, sticky, sweet-tasting, and abundant, is always fertile. Nature is always better for all living things, but it varies because of modern living. There are significant changes in daily activities such as mental stress, disturbed routines, eating habits, sexual activity, and meditation, as well as industrial and occupational hazards. These changes negatively impact *Shukra Dhatu*, which causes infertility. *Shukra* is the terminal tissue, or *Dhatu*, in Ayurveda. It is regarded as the *Sara* of all *Dhatus*. *Shukra Dushti* results from any omission from *Shuddha Shukra Lakshana*. While defining the *Dushti* connected to *Shukra* and *Artava*, vitiated *Vata* and *Pitta* lead to the pathological condition known as *Ksheena Shukra*.

CASE REPORT

A 29-years-old male visited in the OPD of Ayudhara Hospital at Morbi with complain of decreased sexual desire, general debility, fatigability & unable to conceive since 1year. There was no any history of delayed ejaculation, premature ejaculation, erectile dysfunction. His wife failed to conceive inspite unprotected frequent intercourse even during 12 to 18th day of menstruation since last 1 year. The woman was normal at the clinical and endocrinological examination.

Local Examination

No anatomical anomalies were found, and there were no symptoms of inflammation, ulceration, or rashes on the penis, testicles, or scrotum.

Family history: There was no relevant family history

Past medical history

He had no history of tuberculosis, mumps, orchitis, hydrocele, trauma to the gonadal region, or any other chronic, incapacitating illness or potentially fatal emergency. He also had no history of prior surgical procedures, such as herniorrhaphy or vasectomy reconstruction, or consuming gonadotoxic agents.





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Examination:

BP: 122/86 mm of Hg

RR: 16/min

Weight: 65 Kg

Height: 160 Cm

BMI: 25.39 Kg/m²**Ashtavidh Pariksha**

1. NADI (pulse): 71/min

2. MALA (stool): Normal

3. MUTRA (urine): Normal

4. JIVHA (tongue): *Niram*

5. SHABDA (speech): Normal

6. SPARSH (skin): *ushna*

7. DRUK (eyes): Normal

8. AKRITI: *Madhyam*

He was advised semen analysis after proper abstinence. Semen analysis report revealed low sperm concentration (count) and zero progressive motility and 8% non-progressive motility.

Prescribed Medication

1. *Ashwagandha churna* – 3gm OD, after food with milk
2. *kaucha pak* – 1 tsp BD, with milk

Wholesome(Pathya)-Unwholesome(Apathya):[13]

Ahara: *Kshira* (Milk) and its products, *Vilepi* (Gruel), *Ghrta* (Ghee), These dravyas offer *shukrala* and *vrishya* (spermatogenic and aphrodisiac) properties. These include *Rakta Shali* (red variety of rice), *Godhuma* (wheat), *Masha* (black gram), *Kadali* (banana), *Atasi* (*Linum usitatissimum*), *Patola Patra* (*Trichosanthes dioica*), *Alabu Phala* (*Cucurbita lagrenaria*), *Kharjura* (*Phoenix sylvestre*), *Navnita* (butter), *Narikela Ksheera* (coconut milk), *Mandaka* (supernated part of buttermilk), *Amalaki phala* (Indian gooseberry), *Lashuna* (garlic), *Purana Guda* (old jaggery), *sharkara* (sugar candy), and *Saindhava* (rock salt).

Vihara

Abhyanga (body massage), *Vyayama* (exercise), *Snana* (bath), *Nidra* (sleep) and *Suvichara* (positive thoughts), *Pada Prakshalana* (cleanliness of feet).

Apathya

Patients ask to avoid *Katu*, *Tikta*, *Lavana* (Pungent, Bitter, Salt) *Rasa Atisevana*, chewing tobacco, *Adhika Vyavaya* (excessive sexual intercourse), *Ratri jagarana* (late night sleep), *Adhika Shoka* (excessive sorrow), *Adhika Chinta* (anxiety), *Bhaya* (fear), *Vega Dharana* (suppression of natural urge) in routine life style.

RESULTS OF INVESTIGATION

Total duration of treatment was 1 month. Initial sperm count was 6.5 million/ml and total Motility (PR+NP) was 8%. After medicine semen examination report revealed sperm count is 35.5 million/ml and total Motility (PR+NP) is 53% found.

DISCUSSION

In oligoasthenospermia, sperm motility and count are usually observed to be poor. Treatment for oligoasthenospermia should aim to increase sperm motility and count. The reason behind the infertility is *Shukra dushti*. One kind of *Shukra dushti* that is associated with oligoasthenospermia is *Ksheena Shukra*. By using *Vajeekarana Dravya*, the primary aim of *Ksheena Shukra* treatments is *Shukrajanaka* and *Shukrapravartaka* in terms of sperm motility and count. *Acharya Sushruta* says that *Ksheena Shukra* has both *Vata* and *Pitta Doshas*.

Aharaja Nidan(cause) of patient: *ati katu rasa sevana* (excessive spicy food intake)

Viharaj nidana of patient: *Ratri jagarana* (late night sleep), stress





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Samprapti (pathogenesis):

Due to *Aharaja* & *Viharaj nidana sevana*, there is vitiation of *vata* & *pitta Dosha* occurs and it leads to *Ksheena Shukra vyadhi*.

Action of medicine**Ashwagandha curma [14]**

Traditionally, *ashwagandha* has been utilized as a *Rasayana*. *Ashwagandha* root is considered a stimulant, tonic, aphrodisiac, narcotic, diuretic, anthelmintic, astringent, and thermogenic. There are two main categories of processes that *Withania somnifera* uses to affect fertility and the reproductive system: oxidative and non-oxidative mechanisms. The regulation of antioxidant enzymes and the co-factors necessary for their optimal action, as well as the modification of antioxidant activity, are all components of the oxidative process. *Withania somnifera*'s effects on the hypothalamic-pituitary-gonadal (HPG) axis and its antistress effects via the hypothalamic-pituitary-adrenal (HPA) axis are the principal non-oxidative mechanisms. Following ingestion, the extract of *Withania somnifera* is broken down into its primary components, which include withaferin-A, withanolide-D, withanone, and other withanolides. Another connection between male infertility and hormone imbalance resulting from physiological or psychological factors is this. Hormones associated with stress, specifically glucocorticoids, negatively impact the hypothalamic-pituitary-gonadal (HPG) axis, which in turn affects spermatogenesis (Chandra et al., 2012). The anterior pituitary releases FSH and LH in response to stimulation by the hypothalamus' gonadotrophin-releasing hormone (GnRH). Both of them then have an effect on the gonads, regulating their production of testosterone and spermatogenesis. Thus, spermatogenesis suffers when hormones including cortisol, prolactin (PRL), gonadotrophin-inhibiting hormone, and others disturb the HPG axis (Nargund, 2015). Because *Withania somnifera* root extract is regarded as an adaptogen, it can help the body maintain homeostasis by reducing stress and returning cortisol levels to normal, which can help individuals with infertility. As per Shukla et al. (2011), *Withania somnifera* is said to elevate the levels of vital metals such as copper, zinc, iron, and gold. This could potentially facilitate the process of testicular steroidogenesis, wherein more testosterone is synthesized to drive the development of testicular germ cells through spermatogenesis. Along with improving lactate, citrate, alanine, histidine, and phenylalanine concentrations in seminal plasma, *Withania somnifera* may also have important effects on spermatozoa metabolism and spermatogenesis. Thus, patient consume 3 grams of *ashwagandha curma* daily along with milk report improved semen analysis results.

kaucha pak [15]

Ingredients: *Kaucha* (*Mucuna pruriens*), *Godudgha*, *Goghrit*, *Akarkarabha* (*Anacyclus pyrethrum*), *Sunthi* (*Zingiber officinale*), *Lavang* (*Syzygium aromaticum*), *Gokshur* (*Tribulus terrestris*), *Kesar* (*crocus sativus*), *Suddha Hingul*, *Suddha Tankan*, *Dhanyak* (*Coriandrum sativum*), *Kankol* (*piper cubeba*), *Nagabala* (*sida vernicaefolia*), *Vansalochana* (*Bambusa aarundinacea*), *Vang Bhasma*, *Abhrak Bhasma*, *Draksha*, *Sharkara*.

Kaucha pak Indication

Virya vardhaka, *Purisavirajaniya* (To form normal stool), *Buddhivardhak*, *Vataroga nashak* (cure the vatika diseases).

Kaucha/kapikcchu: Levodopa (L-dopa) is the active ingredient in *kaucha* seeds.[16] The neurotransmitter dopamine is formed from the precursor L-dopa. Additionally, it raises the brain's norepinephrine levels. Dopamine's function in regulating mood and pleasure has earned it its status as a "feel-good" neurotransmitter. Supplementing with *Kaucha Pak* may raise dopamine levels, which could improve mental health and mood. As a result, it elevates mood and lowers stress. It is also possible that this activity will increase libido. Its aphrodisiac, androgenic, spermatogenic, and strengthening properties are well-known in Ayurveda. It aids in the treatment of the issue in men thanks to all these qualities. It tones and strengthens the reproductive organs and boosts sexual arousal. *Kaucha* helps males maintain their power, endurance, and self-control. By raising the level of testosterone, it multiplies the sperm population. It encourages fertility and a healthy libido in females. The energy that *kaucha* imparts nourishes the whole body and soothes the nerves, making it a great *vata* rejuvenator.





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Samanya karma of kapikacchu [17-20]

Shukrajanaka (Nourishes *rasaparinatashukra dhatu* possesses similar properties as *shukra dhatu*), *Vrisya* (Aphrodisiac), *Sukrakara* (Spermatogenic), *Balya* (Strengthening), *Brumhna* (Nourishment), *Hridya* (Cardiotonic).

Ghrta: *Shukrajanaka pravartaka* (Used for genesis and also offers ejaculatory effect).

Nagabala: promotes spermatogenesis and aids in the restoration of sexual health; *Shukra sthambhaka*. regulates ejaculation, which is effective in cases of premature ejaculation.

Vanga Bhasma: *Rasayan*, enhances libido for sexual activity, Avoids Nighttime emission, Aids in *Shukra Kshaya* Premature Ejaculation, and Reduces *Daurbalya* (weakness).[21]

CONCLUSION

In this case, we treated *Shukradushti* using Ayurvedic management. We discovered that there was a significant rise in semen parameters, such as sperm count and motility, following the completion of the appropriate treatment based on Ayurvedic medicine and adjustments in food and daily routine. As a result of Dhatus's improved condition and the active components' effects, there was an increase in sperm motility and count as well as a relief from overall debility and fatigability. Positive results like these therefore boost the confidence of Ayurvedic doctors in treating male infertility and inspire to other patients facing the same issue.

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Table 1: Semen Analysis reports

Test name	Before treatment Date: 28/12/2020	After treatment Date: 27/01/2021
Sample type	Fresh	Fresh
Sample volume	2.3 ml	2.1 ml
PH	9.4	9.3
Abstinence	4 days	12 days
Sperm concentration (count)	6.5 million/ml	35.5 million/ml
Total Motility (PR+NP)	8%	53%
Total Progressive Motility (PR)	0%	38%
Non-Progressive Motility (NP)	8%	15%
Immotility	92%	47%
Morphology Normal	NA	9%
Motile Sperm Concentration (MSC)	0.5 million/ml	18.8 million/ml
Progressive Motile Sperm con. (PMSC)	0.0 million/ml	13.6 million/ml
Functional Sperm Concentration (FSC)	NA	2.8 million/ml
Velocity (average path velocity)	< 1m/sec	32 m/sec
Sperm Motility Index (SMI)	0	64
TOTAL PER EJACULATION		
Total sperm number	14.9 million/ej	74.5 million/ej
Total Motile Sperm (PR+NP)	12 million/ej	39.6 million/ej
Total Progressive Motile Sperm con.	0.0 million/ej	28.5 million/ej
Total functional sperm (FSC)	NA	5.9 million/ej
Total Morphology Normal	NA	6.7 million/ej





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Dr. Viral Laheru
M.D. Pathology
Consultant Pathologist
Reg. No. : G-50735

Patient Information			
Patient Name	KRISHNALEKHA AMRUTIYA	Sample Date	28/12/2019 49
Patient ID	4721	Age	29 YEARS
Ref by Dr.	DR DHARMENDRA DHIRYANI	DOB	
Sample Information			
Sample ID	4721	Sample Received Date & Time	28/12/2019 02
Sample Collected Date & Time	28/12/2019 43	Liquefaction Duration	POOR, AFTER 60 MINS
Abstinence	4 Days	Sample Volume	23 ml
Sample Type	FRESH	PH	9.4
WBC Concentration	< 1 MU/ML		
Automated SQA Parameters	RESULTS	REF RANGE	
		WHO 5th	Laboratory
Sperm Concentration (Count)	65 Million/ml	12-16	>=15.0
Total Motility (PR+NP)	8 %	39-42	>=40
Total Progressive Motility (PR)	0 %	31-34	>=32
Non Progressive Motility (NP)	8 %		
Immotility	92 %		
Morphology Normal	N.A. %	3-4	>=4
Motile Sperm Concentration (MSC)	0.5 Million/ml		>=6.0
Progressively Motile Sperm Con (PMSC)	0.0 Million/ml		>=5.0
Functional Sperm Concentration (FSC)	N.A. Million/ml		
Velocity (Average path Velocity) APV	<1 Mic/sec		>=5
Sperm Motility Index (SMI)	0		>=80
TOTAL PER EJACULATION			
Total Sperm Number	14.9 Million/ej	33-46	>=39.0
Total Motile Sperm (PR+NP)	1.2 Million/ej		>=16.0
Total Progressively Motile Sperm (PMSC)	0.0 Million/ej		>=12.0
Total functional Sperm (FSC)	N.A. Million/ej		
Total Morphology Normal	N.A. Million/ej		>=20

SPERM MOTILITY

SPERM MOTILITY INDEX

IMPRESSION :

Fig:1 Before Treatment





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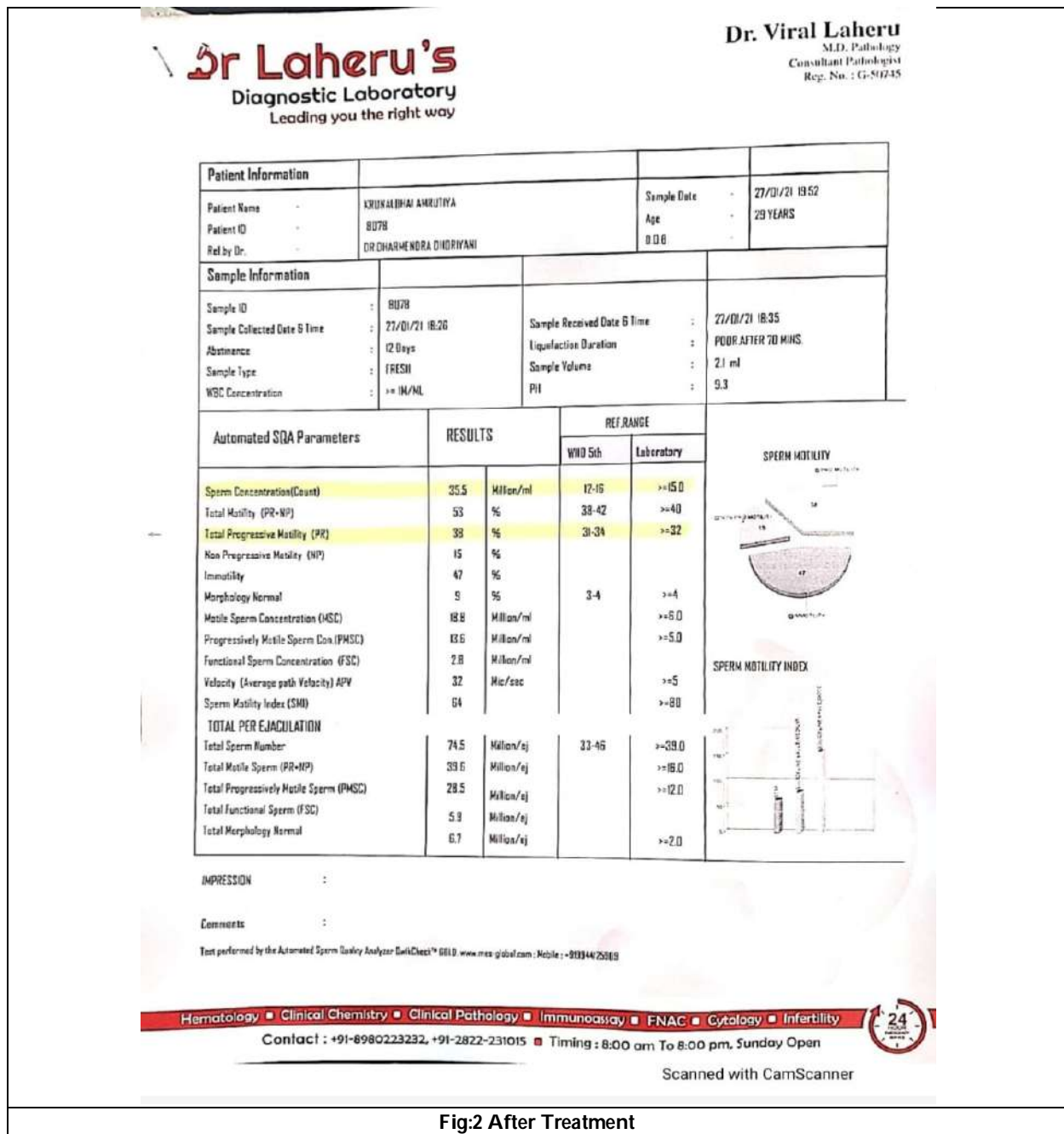


Fig:2 After Treatment





A New Area-Biased Remkan Distribution with Properties and its Applications

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ABSTRACT

In this study, a new two-parameter distribution is proposed. Namely a new Remkan distribution called Remkan distribution. Used in mathematical properties as such moments, survival function, order statistics, hazard rate function, entropy, and Lorenz curves have been discussed. The method of maximum likelihood has been obtained by estimation of parameters. Finally analyzed, a real-life data set is fitted and the fit has been found to be good.

Keywords: Area-biased, Remkan distribution, Likelihood Ratio Test, Bonferroni and Lorenze Curves and Entropy.

INTRODUCTION

Many researchers have recently suggested a new distribution for lifetime data. Used in possess flexibility and statistics in applications. The lifetime data is considered important in research areas such as actuarial science, environmental sciences, biomedical science, and engineering. Whenever comparison of the goodness of fit of the newly classical distribution to available data sets search for new distribution with a better fit. Remkan distribution is a newly proposed two-parameter model. The Remkan distribution has different parameters, η, ϕ . The one-parameter lifetime distributions over proposed years include the Exponential, Lindley, Akash, Sujatha, Ishita, Akshaya, Rama distribution, Pranav, Odoma, Nwike, Iwueze, Juchez, and Chris-Jerry distribution. New two-parameter distributions include the Darna, Hamza, Samade, Alzoubi, and Copoun distributions. The Remkan distribution is a

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three different component density of an exponential (η), gamma ($3, \eta$), and gamma($4, \eta$). The Remkan distribution is skewed, unimodal, right-tailed, and not bell-shaped. (Uwaeme and Akpan). The Remkan distribution was introduced by Uwaeme *et al.* and Akpan *et al.* in 2024. It is a newly proposed two-parametric lifetime model in behavioural science. Many statistical properties have been studied. In this paper, we will discuss Area-biased Remkan distribution.

The Probability Density Function of Remkan Distribution

$$g(x; \eta, \phi) = \frac{\eta^2}{(\eta+2\phi+6)} [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x}; x > 0, \eta > 0, \phi > 0 \quad (1)$$

The Cumulative Distribution Function of Remkan Distribution

$$G(x; \eta, \phi) = 1 - \left[1 + \frac{\eta^3 x^3 + (3+\phi)\eta^2 x^3 + (6+2\phi)\eta x}{\eta+2\phi+6} \right] e^{-\eta x} \quad (2)$$

The Area Based Remkan Distribution (ABRD)

The probability density function of the Area-biased Remkan distribution is given by

$$f_w(x) = \frac{w(x)f(x)}{E(w(x))}; x > 0,$$

Where $w(x)$ be a non-negative weight function and $E(w(x)) = \int w(x)f(x)dx < \infty$.

In this paper, we will consider the Area-biased version of Remkan distribution known as area- based Remkan distribution (ABRD). Consequently, $w(x) = x^2$ the resulting distribution, called area-biased Remkan distribution is given as:

$$f_w(x) = \frac{x^2 f(x)}{E(x^2)}; x > 0$$

Where

$$E(x^2) = \int_0^\infty x^2 f(x; \eta) dx \quad (3)$$

$$= \int_0^\infty x^2 \frac{\eta^2}{(\eta+2\phi+6)} [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx$$

$$E(x^2) = \frac{\eta^2(2\eta+24\phi+120)}{\eta^4(\eta+2\phi+6)} \quad (4)$$

Substitute (1) and (4) in equation (3), and we will get the required probability density function of Area-biased Remkan distribution as

$$f_w(x) = \frac{\eta^4}{(2\eta+24\phi+120)} x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx \quad (5)$$

The cumulative distribution function (cdf) of the Area-biased Remkan distribution (ABRD).

$$F_w(x) = \int_0^x f_w(x) dx \quad (6)$$

$$F_w(x) = \frac{\eta^4}{(2\eta+24\phi+120)} x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx$$

$$= \frac{\eta^4}{(2\eta+24\phi+120)} \int_0^t x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx$$

$$\text{put } x = \frac{t}{\eta}, \eta x = t, dx = \frac{1}{\eta} dt$$

when $x \rightarrow 0, t \rightarrow 0$, and $x \rightarrow \infty, t \rightarrow \infty$

$$= \frac{\eta^4}{(2\eta+24\phi+120)} \int_0^{\eta x} x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx$$

$$F_w(x) = \frac{\eta x(3. \eta x) + \phi \gamma(5, \eta x) + \gamma(6, \eta x)}{(2\eta+24\phi+120)} \quad (7)$$

Reliability Analysis

We will discuss the survival function, failure rate, reverse hazard rate, and the Mills ratio of the Area-biased Remkan distribution (ABRD).

The survival function of the Area-biased Remkan distribution is given by

$$S(x) = 1 - G_1(x; \eta, \phi)$$





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$$S(x) = 1 - \frac{\eta\gamma(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x)}{(2\eta + 24\phi + 120)} \quad (8)$$

The hazard function, also known as the hazard rate is given by

$$h(x) = \frac{g_1(x; \eta, \phi)}{1 - G_1(x; \eta, \phi)}$$

$$h(x) = \left(\frac{\eta^4 x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x}}{(2\eta + 24\phi + 120 - \eta x(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x))} \right) \quad (9)$$

The reverse hazard rate is given by

$$h_r(x) = \frac{g_1(\eta; \phi, \theta)}{G_1(x; \eta, \phi)}$$

$$h_r(x) = \left(\frac{\eta^4 x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x}}{\eta x(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x)} \right) \quad (10)$$

Odds Rate function

$$O(x) = \frac{G_1(x; \eta, \phi)}{1 - G_1(x; \eta, \phi)}$$

$$O(x) = \left(\frac{\eta x(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x)}{(2\eta + 24\phi + 120) - \eta x(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x)} \right)$$

Cumulative hazard rate function

$$H(x) = -\ln(1 - G_1(x; \eta, \phi))$$

$$H(x) = -\ln\left(1 - \frac{\eta\gamma(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x)}{(2\eta + 24\phi + 120)}\right)$$

And the Mills ratio of the Area-biased Remkan distribution is

$$\text{Mills Ratio} = \frac{1}{h_r(x)} \quad \text{Mills Ratio} = \left(\frac{\eta x(3, \eta x) + \phi\gamma(5, \eta x) + \gamma(6, \eta x)}{\eta^4 x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x}} \right)$$

Moments And Associated Measures

Let X denote the random variable of Area-biased Remkan distribution with parameter η and ϕ then the r^{th} order moments $E(X^r)$ of area-biased Remkan distribution are obtained as

$$E(X^r) = \mu_r' = \int_0^\infty x^r g_1(x) dx$$

$$= \int_0^\infty x^r \frac{\eta^4}{(2\eta + 24\phi + 120)} x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx$$

$$= \frac{\eta^4}{(2\eta + 24\phi + 120)} \int_0^\infty x^{r+2} (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x} dx$$

$$E(X^r) = \mu_r' = \frac{\eta \lceil r+3+\phi \rceil r+5+\lceil r+6}{\eta^r (2\eta + 24\phi + 120)} \quad (11)$$

Put $r = 1, 2$, in the equation, we will obtain the first raw moments of Area-biased Remkan distribution, which is given by

$$\mu_1' = \frac{6\eta + 120\phi + 720}{\eta(2\eta + 24\phi + 120)}$$

$$\mu_2' = \frac{24\eta + 720\phi + 5040}{\eta^2(2\eta + 24\phi + 120)}$$

$$\text{Variance} = \mu_2' - (\mu_1')^2$$

$$= \left(\frac{24\eta + 720\phi + 5040}{\eta^2(2\eta + 24\phi + 120)} - \left(\frac{6\eta + 120\phi + 720}{\eta(2\eta + 24\phi + 120)} \right)^2 \right)$$

$$= \left(\frac{24\eta + 720\phi + 5040}{\eta^2(2\eta + 24\phi + 120)} - \frac{(6\eta + 120\phi + 720)^2}{\eta^2(2\eta + 24\phi + 120)^2} \right) \quad (12)$$

Harmonic mean

The harmonic mean of the proposed model can be obtained as

$$H.M = E\left(\frac{1}{x}\right) = \int_0^\infty \frac{1}{x} g_a(x) dx$$

$$= \int_0^\infty \frac{1}{x} \frac{\eta^4}{(2\eta + 24\phi + 120)} x^2 [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx$$





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$$\begin{aligned}
 &= \int_0^{\infty} \frac{\eta^4}{(2\eta+24\phi+120)} x [1 + \phi\eta x^2 + \eta^2 x^3] e^{-\eta x} dx \\
 &= \frac{\eta^4}{(2\eta+24\phi+120)} \int_0^{\infty} x e^{-\eta x} dx + \phi\eta \int_0^{\infty} x^3 e^{-\eta x} dx + \eta^2 \int_0^{\infty} x^4 e^{-\eta x} dx \\
 &= \frac{\eta(\eta^2 + \phi 6 + 24)}{2\eta + 24\phi + 120}
 \end{aligned} \tag{13}$$

Moment Generating Function and Characteristics Function

$$\begin{aligned}
 M_X(t) &= E(e^{tx}) \\
 &= \int_0^{\infty} e^{tx} g_1(x; \eta, \phi) dx
 \end{aligned} \tag{14}$$

Using Taylor's Series Expansion

$$\begin{aligned}
 M_X(t) &= \int_0^{\infty} \left[1 + tx + \frac{(tx)^2}{2!} + \frac{(tx)^3}{3!} + \dots \right] \\
 M_X(t) &= \sum_{j=0}^{\infty} \frac{t^j}{j!} \int_0^{\infty} x^j g_1(x; \eta, \phi) dx \\
 M_X(t) &= \sum_{j=0}^{\infty} \frac{t^j}{j!} \mu_j \\
 M_X(t) &= \sum_{j=0}^{\infty} \frac{t^j}{j!} \left(\frac{\eta \lceil j+3+\phi \rceil j+5+\lceil j+6 \rceil}{\eta^j (2\eta+24\phi+120)} \right)
 \end{aligned} \tag{15}$$

Similarly, the characteristics function of Area-biased Remkan distribution can be obtained by

$$\begin{aligned}
 \phi_X(t) &= M_X(it) \\
 M_X(it) &= \frac{1}{2\eta+24\phi+120} \sum_{j=0}^{\infty} \frac{t^j}{j! \eta^j} (\eta \lceil j+3+\phi \rceil j+5+\lceil j+6 \rceil)
 \end{aligned} \tag{16}$$

Order Statistics

Let $X_{(1)}, X_{(2)}, \dots, X_{(n)}$ be the order statistics of a random sample X_1, X_2, \dots, X_n drawn from the continuous population with probability density function $g_x(x)$ and cumulative distribution function, with $G_x(x)$, then the probability density function of r^{th} order statistics $X_{(r)}$ is given by

$$g_{X(r)}(x) = \frac{n!}{(r-1)!(n-r)!} g_x(x) [G_x(x)]^{r-1} [1 - G_x(x)]^{n-r}$$

The probability density function of r^{th} order statistics $X_{(r)}$ of area-biased Remkan distribution is given by

$$\begin{aligned}
 &= \frac{n!}{(r-1)!(n-r)!} \left(\frac{\eta^4}{2\eta+24\phi+120} x^2 (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x} \right) \\
 &\times \left(\frac{1}{2\eta+24\phi+120} \eta \gamma(3, \eta x) + \phi \gamma(5, \eta x) + \gamma(6, \eta x) \right)^{r-1} \\
 &\times \left(1 - \frac{1}{2\eta+24\phi+120} \eta \gamma(3, \eta x) + \phi \gamma(5, \eta x) + \gamma(6, \eta x) \right)^{n-r}
 \end{aligned}$$

Therefore, the probability density function of first-order statistics of Area-biased Remkan distribution can be obtained as

$$\begin{aligned}
 g_{X(1)}(x) &= \frac{n(n-1)!}{(1-1)!(n-1)!} \left(\frac{\eta^4}{2\eta+24\phi+120} x^2 (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x} \right) \\
 &\times \left(1 - \frac{1}{2\eta+24\phi+120} \eta \gamma(3, \eta x) + \phi \gamma(5, \eta x) + \gamma(6, \eta x) \right)^{n-1} \\
 g_{X(n)}(x) &= \frac{n!}{(n-1)!(1-1)!} \left(\frac{\eta^4}{2\eta+24\phi+120} x^2 (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x} \right) \\
 &\times \left(\frac{1}{2\eta+24\phi+120} \eta \gamma(3, \eta x) + \phi \gamma(5, \eta x) + \gamma(6, \eta x) \right)^{n-1}
 \end{aligned} \tag{17}$$

Likelihood Ratio Test



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Let X_1, X_2, \dots, X_n be a random sample from the area-biased Remkan distribution. To test the hypothesis

$$H_0: g(x) = g(x; \eta, \phi) \quad \text{against} \quad H_1: g(x) = g_a(x; \eta, \phi)$$

In order to test whether the random sample of size n comes from the Area-biased Remkan distribution, the following test statistics are used by

$$\begin{aligned} \Delta &= \frac{L_1}{L_0} = \prod_{i=1}^n \frac{g_a(x; \eta, \phi)}{g(x; \eta, \phi)} \\ &= \prod_{i=1}^n \left(\frac{\frac{\eta^4}{2\eta+24\phi+120} x^2 (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x}}{\frac{\eta^2}{\eta+2\phi+6} (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x}} \right) \\ &= \prod_{i=1}^n \frac{\eta^2(\eta+2\phi+6)}{2\eta+24\phi+120} x_i^2 \\ &= \left(\frac{\eta^2(\eta+2\phi+6)}{2\eta+24\phi+120} \right)^n \prod_{i=1}^n x_i^2 \end{aligned}$$

We should reject the null hypothesis, if

$$\Delta = \left(\frac{\eta^2(\eta+2\phi+6)}{2\eta+24\phi+120} \right)^n \prod_{i=1}^n x_i^2 > k \quad (\text{or})$$

Equivalently, We shall reject the null hypothesis, if

$$\Delta^* = \prod_{i=1}^n x_i^2 > k \left(\frac{2\eta+24\phi+120}{\eta^2(\eta+2\phi+6)} \right)^n$$

$$\Delta^* = \prod_{i=1}^n x_i^2 > k^* \quad \text{where,}$$

$$k^* = k \left(\frac{2\eta+24\phi+120}{\eta^2(\eta+2\phi+6)} \right)^n$$

Then

$p(\Delta^* > \lambda^*)$, where, $\lambda^* = \prod_{i=1}^n x_i^2$ is less than a specified level of significance, and $\prod_{i=1}^n x_i^2$ is the observed value of Δ^*

Maximum Likelihood Estimate And Fisher Information Measure

$$L(x) = \prod_{i=1}^n g_a(x_i)$$

$$L(x) = \prod_{i=1}^n \frac{\eta^4}{2\eta+24\phi+120} x_i^2 (1 + \phi\eta x_i^2 + \eta^2 x_i^3) e^{-\eta x_i}$$

$$L(x) = \frac{\eta^{4n}}{(2\eta+24\phi+120)^n} \prod_{i=1}^n x_i^2 (1 + \phi\eta x_i^2 + \eta^2 x_i^3) e^{-\eta x_i} \quad (19)$$

The log likelihood function is given by equation (19)

$$= n \log(\eta^4) - n \log(2\eta+24\phi+120) + 2 \sum_{i=1}^n \log x_i + \sum_{i=1}^n \log(1 + \phi\eta x_i^2 + \eta^2 x_i^3) - \eta \sum_{i=1}^n x_i$$

Now, differentiating with respect to η and ϕ

$$\frac{\partial \log L}{\partial \eta} = n \left(\frac{4\eta^3}{\eta^4} \right) - n \frac{2}{(2\eta+24\phi+120)} + \sum_{i=1}^n \frac{(\phi x_i^2 + 2\eta x_i^3)}{(1 + \phi\eta x_i^2 + \eta^2 x_i^3)} - \sum_{i=1}^n x_i = 0$$

$$\frac{\partial \log L}{\partial \phi} = -n \frac{24}{(2\eta+24\phi+120)} + \sum_{i=1}^n \frac{(\eta x_i^2)}{(1 + \phi\eta x_i^2 + \eta^2 x_i^3)} = 0 \quad (20)$$

For the purpose of obtaining the confidence interval we use the asymptotic normality results. We have that if

$\hat{\lambda} = (\hat{\eta}, \hat{\phi})$ denotes the MLE of $\lambda = (\eta, \phi)$ We can state the results as follows

$$\sqrt{n}(\hat{\lambda} - \lambda) \rightarrow N_2(0, I^{-1}(\lambda))$$

Where, $I(\lambda)$ is Fisher's Information Matrix. i.e.,





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$$I(\lambda) = -\frac{1}{n} \begin{bmatrix} E \left[\frac{\partial^2 \log L}{\partial \eta^2} \right] & E \left[\frac{\partial^2 \log L}{\partial \eta \partial \phi} \right] \\ E \left[\frac{\partial^2 \log L}{\partial \phi \partial \eta} \right] & E \left[\frac{\partial^2 \log L}{\partial \phi^2} \right] \end{bmatrix}$$

Where,

$$\begin{aligned} \left[\frac{\partial^2 \log L}{\partial \eta^2} \right] &= E \left[\frac{\partial}{\partial \eta} \left(\frac{\partial \log L}{\partial \eta} \right) \right] \\ \left[\frac{\partial^2 \log L}{\partial \eta^2} \right] &= n \left(\frac{12\eta^6 - 16\eta^6}{\eta^8} \right) - n \frac{-4}{(2\eta + 24\phi + 120)^2} + \frac{2x_i^3 + 2\phi\eta x_i^5 + 2\eta^2 x_i^6 - 2\phi x_i^2 + 2\eta x_i^3}{(1 + \phi\eta x_i^2 + \eta^2 x_i^3)^2} \end{aligned} \quad (21)$$

$$\begin{aligned} \left[\frac{\partial^2 \log L}{\partial \phi^2} \right] &= E \left[\frac{\partial}{\partial \phi} \left(\frac{\partial \log L}{\partial \phi} \right) \right] \\ \left[\frac{\partial^2 \log L}{\partial \phi^2} \right] &= -n \frac{-576}{(2\eta + 24\phi + 120)^2} - \frac{-\eta^2 x_i^4}{(1 + \phi\eta x_i^2 + \eta^2 x_i^3)^2} \end{aligned} \quad (22)$$

$$\left[\frac{\partial^2 \log L}{\partial \eta \partial \phi} \right] = -n \frac{-48}{(2\eta + 24\phi + 120)^2} + \frac{x_i^2 + 2\eta^4 x_i^{10}}{(1 + \phi\eta x_i^2 + \eta^2 x_i^3)^2} \quad (23)$$

Bonferroni And Lorenz Curves

The Bonferroni and Lorenz curves are used in economics in order to study income, etc., but they are used in other fields like demography, insurance, medicine, and reliability. The Bonferroni and Lorenz curves are given by

$$B(p) = \frac{1}{p\mu_1} \int_0^q xg(x)dx$$

$$B(p) = \frac{1}{p\mu_1} \int_0^q xg(x; \eta, \phi)dx$$

and

$$L(p) = \frac{1}{\mu_1} \int_0^q xg(x; \eta, \phi)dx$$

Where, $q = G^{-1}(p)$; $q \in [0, 1]$ and $\mu = (x)$

Hence, the Bonferroni and Lorenz curves of our distribution are given by,

$$\mu = \frac{6\eta + 120\phi + 720}{\eta(2\eta + 24\phi + 120)}$$

$$\begin{aligned} B(p) &= \frac{\eta(2\eta + 24\phi + 120)}{6\eta + 120\phi + 720} \int_0^q \frac{\eta^4}{2\eta + 24\phi + 120} x^2 (1 + \phi\eta x_i^2 + \eta^2 x_i^3) e^{-\eta x} dx \\ &= \frac{\eta^4}{6\eta + 120\phi + 720} \int_0^q x^2 (1 + \phi\eta x_i^2 + \eta^2 x_i^3) e^{-\eta x} dx \\ &= \frac{\eta^4}{6\eta + 120\phi + 720} \int_0^q x^2 e^{-\eta x} dx + \phi\eta \int_0^q x^4 e^{-\eta x} dx + \eta^2 \int_0^q x^5 e^{-\eta x} dx \end{aligned}$$

$$\text{Put, } x = \frac{t}{\eta}, \quad \eta x = t, \quad dx = \frac{1}{\eta} dt$$

when $x \rightarrow 0, t \rightarrow 0$, and $x \rightarrow q, t \rightarrow \eta q$

$$= \frac{\eta^4}{6\eta + 120\phi + 720} \frac{1}{\eta^3} \int_0^{\eta q} t^2 e^{-t} dt + \frac{1}{\phi\eta^6} \int_0^{\eta q} t^4 e^{-t} dt + \frac{1}{\eta^8} \int_0^{\eta q} t^5 e^{-t} dt$$

After the simplification, we get

$$B(p) = \frac{\eta(\eta\gamma(3, \eta q) + \phi(5, \eta q) + (6, \eta q))}{(6\eta + 120\phi + 720)}$$

Where,

$$L(p) = B(p)$$

$$L(p) = \frac{\eta(\eta\gamma(3, \eta q) + \phi(5, \eta q) + (6, \eta q))}{(6\eta + 120\phi + 720)} \quad (24)$$

Entropies





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Entropy is important in different areas such as probability and economics, communication theory, physics, and statistics. Entropies are applied to quantify a system's diversity, uncertainty, or randomness. An indicator of the uncertainty's variation is the entropy of a random variable X .

Renyi Entropy

The Renyi entropy is significant as a diversity index. The Renyi entropy is also important in quantum information. It can be used as a measure of entanglement for a given probability distribution. Renyi entropy is given by

$$R_\lambda = \frac{1}{1-\lambda} \log \int_0^\infty (g(x))^\lambda dx; \lambda > 0, \lambda \neq 1$$

$$R_\lambda = \frac{1}{1-\lambda} \log \int_0^\infty (g(x; \eta, \phi))^\lambda dx$$

$$R_\lambda = \frac{1}{1-\lambda} \log \int_0^\infty \left(\frac{\eta^4}{2\eta + 24\phi + 120} x^2 (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x} \right)^\lambda dx$$

$$R_\lambda = \frac{1}{1-\lambda} \log \left(\frac{\eta^4}{2\eta + 24\phi + 120} \right)^\lambda \int_0^\infty x^{2\lambda} (1 + \phi\eta x^2 + \eta^2 x^3)^\lambda e^{-\lambda\eta x} dx \quad (25)$$

Using binomial expansion

$$= \sum_{i=0}^{\lambda} \binom{\lambda}{i} 1^{\lambda-i} (\phi\eta x^2 + \eta^2 x^3)^i$$

$$R_\lambda = \frac{1}{1-\lambda} \log \left(\frac{\eta^4}{2\eta + 24\phi + 120} \right)^\lambda \sum_{i=1}^{\lambda} \sum_{j=0}^i \binom{\lambda}{i} \binom{i}{j} (\phi\eta)^{i-j} \eta^{2j} \int_0^\infty x^{(2\lambda+2i+j+1)-1} e^{-\lambda\eta x} dx$$

$$R_\lambda = \frac{1}{1-\lambda} \log \left(\frac{\eta^4}{2\eta + 24\phi + 120} \right)^\lambda \sum_{i=1}^{\lambda} \sum_{j=0}^i \binom{\lambda}{i} \binom{i}{j} (\phi\eta)^{i-j} \eta^{2j} \frac{\Gamma(2\lambda + 2i + j + 1)}{(\eta\lambda)^{2\lambda+2i+j+1}}$$

Tsallis Entropy

The Boltzmann-Gibbs (B-G) statistical property generalization initiated by Tsallis has received a great deal of attention. This B-G statistic was first introduced as the mathematical expansion of Tsallis entropy (Tsallis, 1988) for continuous random variables; this generalization of B-G was introduced in order to suggest. Which is defined as

$$T_\lambda = \frac{1}{\lambda-1} \left(1 - \int_0^\infty (g_w(x; \eta, \phi))^\lambda dx \right) \lambda > 0, \lambda \neq 1$$

$$T_\lambda = \frac{1}{\lambda-1} \left(1 - \int_0^\infty \left(\frac{\eta^4}{2\eta + 24\phi + 120} x^2 (1 + \phi\eta x^2 + \eta^2 x^3) e^{-\eta x} \right)^\lambda dx \right)$$

$$T_\lambda = \frac{1}{\lambda-1} \left(1 - \left(\frac{\eta^4}{2\eta + 24\phi + 120} \right)^\lambda \int_0^\infty x^{2\lambda} (1 + \phi\eta x^2 + \eta^2 x^3)^\lambda e^{-\lambda\eta x} dx \right) \quad (26)$$

Using binomial expansion

$$= \sum_{i=0}^{\lambda} \binom{\lambda}{i} 1^{\lambda-i} (\phi\eta x^2 + \eta^2 x^3)^i$$

$$T_\lambda = \frac{1}{1-\lambda} \left(1 - \left(\frac{\eta^4}{2\eta + 24\phi + 120} \right)^\lambda \sum_{i=1}^{\lambda} \sum_{j=0}^i \binom{\lambda}{i} \binom{i}{j} (\phi\eta)^{i-j} \eta^{2j} \int_0^\infty x^{(2\lambda+2i+j+1)-1} e^{-\lambda\eta x} dx \right)$$

$$T_\lambda = \frac{1}{1-\lambda} \left(1 - \left(\frac{\eta^4}{2\eta + 24\phi + 120} \right)^\lambda \sum_{i=1}^{\lambda} \sum_{j=0}^i \binom{\lambda}{i} \binom{i}{j} (\phi\eta)^{i-j} \eta^{2j} \frac{\Gamma(2\lambda + 2i + j + 1)}{(\eta\lambda)^{2\lambda+2i+j+1}} \right)$$

Data Analysis





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The data under consideration are we demonstrate the applicability of the lifetime's data relating to show that Area-biased Remkan distribution can be better than Remkan distribution. We consider a data set of 18 patients suffering from leukaemia blood cancer (non-censored data) are the data sets. 1.013,1.034,1.109,1.226,1.509,1.533,1.563,1.716,1.929,1.965,2.061,2.344,2.546,2.626,2.778,2.951, 4.118,5.136 In order to compare the performance of Area-biased Remkan distribution with Remkan distribution. We are using the criteria values, like *AIC* (Akaike information criterion), *AICC* (corrected Akaike information criterion) and *BIC* (Bayesian information criterion). The better distribution corresponds to lesser values of *AIC*, *AICC*, *BIC* and $-2\log L$ can be evaluated by using the formulas as follows:

$$AIC = 2K - 2\log L \quad AICC = AIC + \frac{2k(k+1)}{(n-k-1)} \text{ and } BIC = k \log n - 2\log L$$

Where, K = number of parameters, n sample size and $-2\log L$ is the maximized value of loglikelihood function.

From the table, it can be observed that the result is an Area-biased Remkan distribution have *AIC*, *BIC*, *AICC*, $-2\log L$, and compared to the values of Remkan, Aradhana, Ishita, Akshaya, Shankar, Rama, Exponential, Lindly, and Akash distributions. Our conclusion is the area-biased Remkan distribution, given the better fits over the above other distributions.

CONCLUSION

In this study the present a new two-parameter life-time distribution and proposed various statistical properties of the distribution, derived as cumulative distribution, survival, hazard, and moments. A simulation of the study has been presented. The data can be used to describe the behavioural structure of data in life from engineering and medical science. The Area-biased Remkan distribution in applications has been compared for goodness of fit to Remkan, Aradhana, Ishita, Akshaya, Shankar, Rama, Exponential, Lindly, and Akash distributions. The MLE has been discussed, and the several statistical measures that make it suitable for reliability behaviour as a life-time distribution are over all well-known and considered. The Area-biased Remkan distribution provides better performance than Remkan distribution. The results show that it better fit over the other distributions.

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Table.1: MLEs AIC, BIC, AICC, and $-2\log L$ of the fitted distribution for given data set

Distribution	ML Estimates	-2logL	AIC	BIC	AICC
Area-biased Remkan Distribution	$\hat{\eta} = 2.298547e + 00$ ($2.422886e - 01$) $\hat{\phi} = 1.932674e + 04$ ($3.355444e + 04$)	47.47339	51.47339	53.25414	52.27339
Remkan	$\hat{\eta} = 1.399119e + 00$ ($1.876752e - 01$) $\hat{\phi} = 1.727931e + 04$ ($3.355444e + 04$)	49.6749	53.6749	55.45564	54.4749
Aradhana	$\hat{\theta} = 0.985545$ (0.135948)	60.60053	62.60053	63.54497	62.8227
Ishita	$\hat{\theta} = 0.09975990$ (0.11344076)	62.74297	64.74297	65.68741	64.9651
Akshaya	$\hat{\theta} = 1.2738546$ (0.1506672)	58.05546	60.05546	60.9999	60.2776
Shankar	$\hat{\theta} = 0.7124395$ (0.10777871)	63.08856	65.08856	66.033	65.3107
Rama	$\hat{\theta} = 1.3784229$ (0.1415338)	62.41991	64.41991	65.36435	64.6421
Exponential	$\hat{\theta} = 0.7076860$ (0.1200725)	68.65501	70.65501	71.59945	70.8772
Lindley	$\hat{\theta} = 0.7076860$ (0.1200725)	64.02158	66.02158	66.96602	66.2438
Akash	$\hat{\theta} = 0.0297001$ (0.1317933)	62.69158	64.69158	65.63602	64.9138

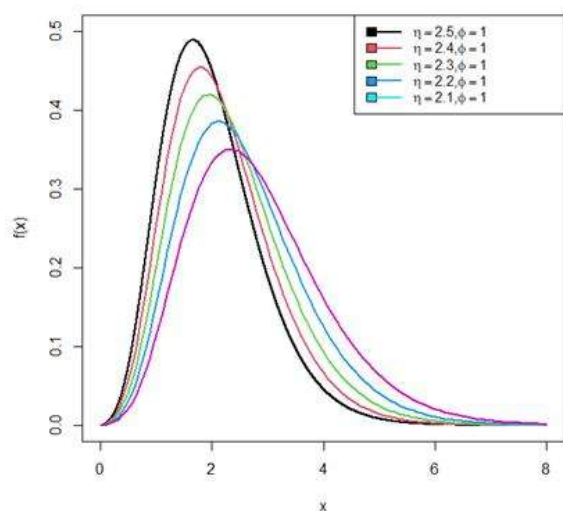


Figure.1: Pdf Plot of Area-biased Remkan Distribution

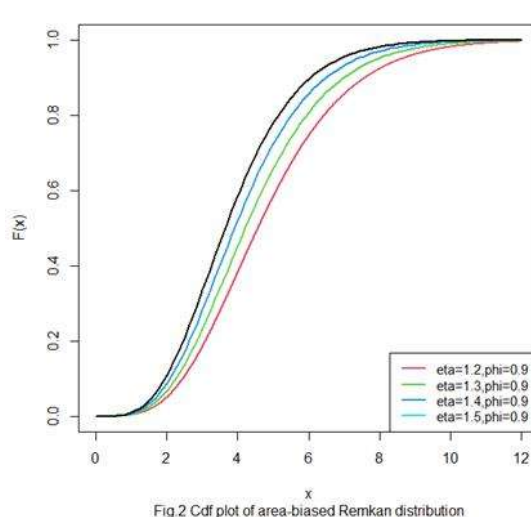


Figure.2: Cdf Plot of Area-biased Remkan Distribution



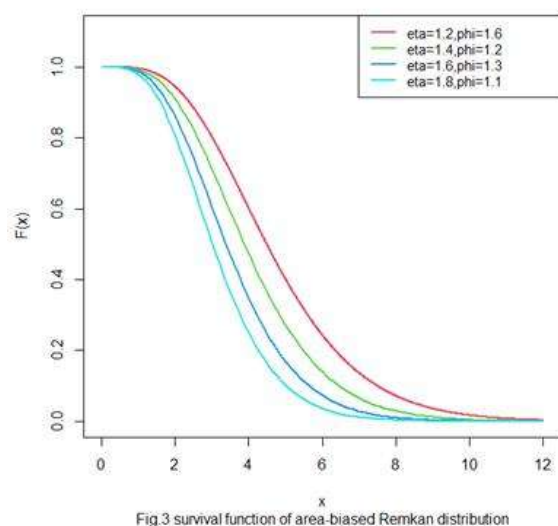


Figure.3:Survival Function of Area-biased Remkan Distribution

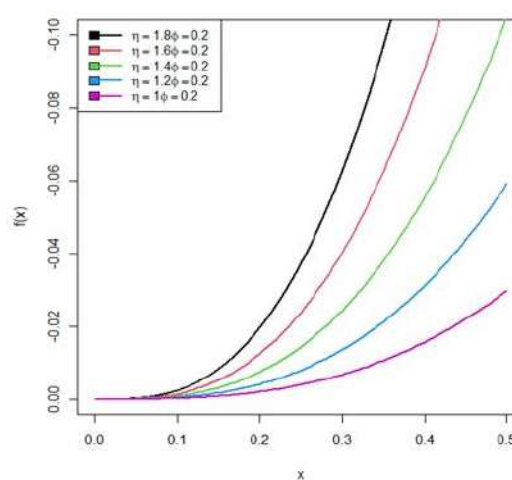


Figure.4: Showing Hazard Function of Area-biased Remkan Distribution





On Interval-Valued Closed Sets and their Generalizations in Interval-Valued Topological Spaces

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ABSTRACT

Defining several types of Interval-Valued sets and their generalizations is the aim of this study. Furthermore, we define few Interval-Valued sets in their weak and strong forms. We also spoke about the relationships that exist between the various kinds of Interval-Valued closed sets and their generalized sets. Using precise examples, we clarified such relationships.

Keywords: Interval-Valued closed sets; Interval-Valued generalization of closed sets; Interval-Valued weakly closed set.

Mathematics Subject Classification(2020) : 54A05

INTRODUCTION

Yao [1] introduced an interval set in 2009 (which we will henceforth refer to as an Interval-Valued set) that offered an algebraic structural explanation as well as an approximation tool for concepts that were hard or impossible to define. This concept is unmistakably an extension of classical sets and a specific case of Zadeh's Interval-Valued fuzzy sets [2]. One of the reasons for its birth is to provide a point-set based context for the classical sets. We review a number of





definitions for an Interval-Valued set that Yao has worked on. The concept of interiors and closures with interval values, as well as how Kim J. et al. [3] determined some of their properties. Interval-Valued sets offer a more adaptable framework for encapsulating ambiguity and uncertainty in real-world data. The notion of generalized closed sets, which are a generalization of closed sets in topological spaces, was first presented by Levin [4] in 1970. Here, we defined a few types of Interval-Valued closed sets with some generalizations of them. We also discussed the relationships between the Interval-Valued closed sets we defined here; these implications are not reversible ones explained with perfect examples, and the remarks show some independent relations with counter examples.

PRELIMINARIES

We can recall the following definitions which will be used later.

Definition 2.1[3] In a non empty set X . The form $[\mathcal{M}^-, \mathcal{M}^+] = \{\mathcal{N} \subset X: \mathcal{M}^- \subset \mathcal{N} \subset \mathcal{M}^+\}$ is called an Interval-Valued set (briefly, IVS) in X , if $[\mathcal{M}^-, \mathcal{M}^+] \subset X$ and $\mathcal{M}^- \subset \mathcal{M}^+$. In this case, \mathcal{M}^- [resp. \mathcal{M}^+] represent the set of minimum [resp. maximum] membership of elements of X to \mathcal{M} . The set of all IVSs in X is denoted by $\text{IVS}(X)$.

Definition 2.2[3] A non-empty set X and \mathcal{M}, \mathcal{N} are IVSs in the form $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$, $\mathcal{N} = [\mathcal{N}^-, \mathcal{N}^+]$ respectively. Then

1. $[\mathcal{M}^-, \mathcal{M}^+] \subset [\mathcal{N}^-, \mathcal{N}^+], \Leftrightarrow \mathcal{M}^- \subset \mathcal{N}^-$ and $\mathcal{M}^+ \subset \mathcal{N}^+$.
2. $[\mathcal{M}^-, \mathcal{M}^+] = [\mathcal{N}^-, \mathcal{N}^+], \Leftrightarrow [\mathcal{M}^-, \mathcal{M}^+] \subset [\mathcal{N}^-, \mathcal{N}^+]$ and $[\mathcal{N}^-, \mathcal{N}^+] \subset [\mathcal{M}^-, \mathcal{M}^+]$.
3. $([\mathcal{M}^-, \mathcal{M}^+])^c = [\mathcal{M}^{+c}, \mathcal{M}^{-c}]$.
4. $[\mathcal{M}^-, \mathcal{M}^+] \cup [\mathcal{N}^-, \mathcal{N}^+] = [\mathcal{M}^- \cup \mathcal{N}^-, \mathcal{M}^+ \cup \mathcal{N}^+]$.
5. $[\mathcal{M}^-, \mathcal{M}^+] \cap [\mathcal{N}^-, \mathcal{N}^+] = [\mathcal{M}^- \cap \mathcal{N}^-, \mathcal{M}^+ \cap \mathcal{N}^+]$.

Definition 2.3[3] Let τ be a family of non-empty IVSs on X , where X be a non-empty set. If it meets the following axioms, then τ is called an Interval-Valued Topology (briefly, IVT) on X :

1. $\emptyset, \tilde{X} \in \tau$.
2. $\mathcal{M} \cap \mathcal{N} \in \tau$ for any $\mathcal{M}, \mathcal{N} \in \tau$.
3. $\bigcup_{j \in J} \mathcal{M}_j \in \tau$ for any family $(\mathcal{M}_j)_{j \in J}$ of members of τ .

This pair (X, τ) is referred as an Interval-Valued topological space (briefly, IVTS), in this instance and each member of τ is referred as an Interval-Valued open set (briefly, IVOs) in X . If $\mathcal{M}^c \in \tau$, then an IVS \mathcal{M} is known as an Interval-Valued closed set (briefly, IVCs) in X .

Definition 2.4[3] Let (X, τ) be an IVTS and let $\mathcal{M} \in \text{IVS}(X)$. Then

1. The Interval-Valued closure of $[\mathcal{M}^-, \mathcal{M}^+]$ w.r.t. τ , denoted by $\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])$, is an IVS in X defined as:
 $\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+]) = \bigcap \{K: K^c \in \tau \text{ and } \mathcal{M} \subset K\}$.
2. The Interval-Valued interior of $[\mathcal{M}^-, \mathcal{M}^+]$ w.r.t. τ , denoted by $\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])$, is an IVS in X defined as:
 $\text{IVint}([\mathcal{M}^-, \mathcal{M}^+]) = \bigcup \{G: G \in \tau \text{ and } G \subset \mathcal{M}\}$

Proposition 2.5[3] Let (X, τ) be an IVTS and let $[\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$. Then

1. $\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])^c = (\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+]))^c$.
2. $\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])^c = (\text{IVint}([\mathcal{M}^-, \mathcal{M}^+]))^c$.

Definition 2.6[3] Kuratowski Closure Axioms. Let $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$, $\mathcal{N} = [\mathcal{N}^-, \mathcal{N}^+] \in \text{IVS}(X)$ and (X, τ) be IVTS. Then

1. If $[\mathcal{M}^-, \mathcal{M}^+] \subset [\mathcal{N}^-, \mathcal{N}^+]$, then $\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+]) \subset \text{IVcl}([\mathcal{N}^-, \mathcal{N}^+])$.
2. $\text{IVcl}(\emptyset) = \emptyset$.
3. $[\mathcal{M}^-, \mathcal{M}^+] \subset \text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])$.
4. $\text{IVcl}(\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])) = \text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])$.
5. $\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+] \cup [\mathcal{N}^-, \mathcal{N}^+]) = \text{IVcl}([\mathcal{M}^-, \mathcal{M}^+]) \cup \text{IVcl}([\mathcal{N}^-, \mathcal{N}^+])$.





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Definition 2.7[3] Let $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$, $\mathcal{N} = [\mathcal{N}^-, \mathcal{N}^+] \in \text{IVS}(X)$ and (X, τ) be IVTS. Then

1. If $[\mathcal{M}^-, \mathcal{M}^+] \subset [\mathcal{N}^-, \mathcal{N}^+]$, then $\text{IVint}[\mathcal{M}^-, \mathcal{M}^+] \subset \text{IVint}([\mathcal{N}^-, \mathcal{N}^+])$.
2. $\text{IVcl}(\bar{X}) = \bar{X}$.
3. $\text{IVint}([\mathcal{M}^-, \mathcal{M}^+]) \subset [\mathcal{M}^-, \mathcal{M}^+]$.
4. $\text{IVint}(\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])) = \text{IVint}([\mathcal{M}^-, \mathcal{M}^+])$.
5. $\text{IVint}([\mathcal{M}^-, \mathcal{M}^+] \cap [\mathcal{N}^-, \mathcal{N}^+]) = \text{IVint}([\mathcal{M}^-, \mathcal{M}^+]) \cap \text{IVint}([\mathcal{N}^-, \mathcal{N}^+])$.

Definition 2.8[5] A set $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ from $\text{IVS}(X)$ is an Interval-Valued generalized closed (briefly, IVg-closed set) iff $\text{IVcl}[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ whenever $\mathcal{M} \subseteq U$ where U is an IVOs. A set $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ from $\text{IVS}(X)$ is said to be an Interval-Valued generalized open (briefly, IVg-open set) whenever $\bar{X} - [\mathcal{M}^-, \mathcal{M}^+]$ is an IVg-closed set.

Definition 2.9[5] Intersection of all IVg-closed sets containing $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued generalized closure of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVgcl}(\mathcal{M})$. Union of all IVg-open sets contained in $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued generalized interior of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVgint}(\mathcal{M})$.

Definition 2.10[6] Let (X, τ) be an IVTS(X). $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ is said to be an Interval-Valued semi open set [briefly, IVSOs] if $[\mathcal{M}^-, \mathcal{M}^+] \subseteq \text{IVcl}(\text{IVint}([\mathcal{M}^-, \mathcal{M}^+]))$ and its complement is an Interval-Valued semi closed set [briefly, IVSCs].

Definition 2.11[6] Take $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ and (X, τ) be an IVTS. If $\text{IVscl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq [U^-, U^+]$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ and U is an IVSOs. Then $\text{IVS} [\mathcal{M}^-, \mathcal{M}^+]$ is known as Interval-valued semi generalized closed set [briefly, IVsg-closed set]. The complement of IVsg-closed set is known as an Interval-Valued semi generalized open (IVsg-open set, for short).

Definition 2.12[6] Intersection of all IVsg-closed sets containing $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued semi generalized closure of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVsgcl}(\mathcal{M})$.

Union of all IVsg-open sets contained in $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued semi generalized interior of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVsgint}(\mathcal{M})$.

Definition 2.13[6] A set $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ is said to be Interval-Valued generalized semiclosed [briefly, IVgs-closed] if $\text{IVscl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq [U^-, U^+] = U$ whenever, U is an Interval-Valued open in X . The complement of IVgs-closed set is denoted as IVgs-open set.

Definition 2.14[6] Intersection of all IVgs-closed sets containing $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called Interval-Valued generalized semi closure of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVgscl}(\mathcal{M})$.

Union of all IVgs-open sets contained in $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued generalized semi interior of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVgsint}(\mathcal{M})$.

SOME IV CLOSED SETS

The following definitions are introduced here.

Definition 3.1 Let (X, τ) be an IVTS(X). $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ is said to be an Interval-Valued pre open set [briefly, IVPOs] if $[\mathcal{M}^-, \mathcal{M}^+] \subseteq \text{IVint}(\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+]))$ and its complement is an Interval-Valued pre closed set [briefly, IVPCs].

Definition 3.2 A set $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ is said to be an Interval-Valued pre semiopen set [briefly, IVPSOs] if $[\mathcal{M}^-, \mathcal{M}^+] \subseteq \text{IVint}(\text{IVcl}(\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])))$ and \mathcal{M}^c is an Interval-Valued pre semi closed set [briefly, IVPSCs].





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Definition 3.3 (X, τ) be an IVTS(X). If $[\mathcal{M}^-, \mathcal{M}^+] \subseteq \text{IVcl}(\text{IVint}(\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])))$. Then $[\mathcal{M}^-, \mathcal{M}^+]$ is considered as an Interval-Valued semi pre open set [briefly, IVSPOs] and \mathcal{M}^c is an Interval-Valued semi pre closed set [briefly, IVSPCs].

Definition 3.4 Intersection of all IVPC sets (resp. IVSPCs, IVPSCs) containing $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued pre closure (resp. Interval-Valued semi pre closure, Interval-Valued pre semi closure) of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVpcl}(\mathcal{M})$ (resp. $\text{IVspcl}(\mathcal{M})$, $\text{IVpscl}(\mathcal{M})$).

Definition 3.5 Take $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ and (X, τ) be an IVTS. If $\text{IVpcl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq U$ (resp. $\text{IVspcl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq U$, $\text{IVpscl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq U$) whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$, where U is an IVOs. Then $\text{IVS} [\mathcal{M}^-, \mathcal{M}^+]$ is known as Interval-Valued generalized pre closed set [briefly, IVgp-closed set] (resp. Interval-Valued generalized semi pre closed set [briefly, IVgsp-closed set], Interval-Valued pre semi generalized closed set [briefly, IVpsg-closed set])
The complement of IVgp-closed set (resp. IVgsp-closed set, IVpsg-closed set) is known as Interval-Valued generalized pre open set (IVgp-open set, for short) (resp. Interval-Valued generalized semi pre open set (IVgsp-open set, for short), Interval-Valued pre semi generalized-open set (IVpsg-open set, for short)).

Definition 3.6 A set $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in \text{IVS}(X)$ is said to be an Interval-Valued pre generalized closed set [briefly, IVpg-closed set] (resp. Interval-Valued generalized pre semi closed set [briefly, IVgps-closed set]) if $\text{IVpcl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq U$ (resp. $\text{IVpscl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq U$) whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$, where U is an IVOs (resp. IVPSO) in X .
The complement of IVpg-closed and IVgps-closed is called as Interval-Valued pre generalized open set and Interval-Valued generalized pre semi open set. It is denoted by IVpg-open set and IVgps-open set respectively.

Definition 3.7 Intersection of all IVpg-closed set (resp. IVgp-closed set, IVgsp-closed set, IVgps-closed set and IVpsg-closed set) containing $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued pre generalized closure (resp. Interval-Valued generalized pre closure, Interval-Valued generalized semi pre closure, Interval-Valued generalized pre semi closure, Interval-Valued pre semi generalized closure) of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVpgcl}(\mathcal{M})$ (resp. $\text{IVgpcl}(\mathcal{M})$, $\text{IVgspcl}(\mathcal{M})$, $\text{IVgpscl}(\mathcal{M})$, $\text{IVpsgcl}(\mathcal{M})$).

Definition 3.8 In IVTS (X, τ) take a IVS, $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is said to be

1. Interval-Valued weakly closed set [briefly, IVWCs] if $\text{IVcl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq U$ and U is an IVSOs in X .
2. Interval-Valued weakly generalized closed set [briefly, IVwg-closed set] if $\text{IVcl}(\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])) \subseteq U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq U$ and U is an IVOs in X .
3. Interval-Valued strongly generalized semi closed set [briefly, IVg*-closed set] if $\text{IVcl}(\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])) \subseteq U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq U$ and U is an IVg-open set in X .
4. Interval-Valued semi weakly generalized closed set [briefly, IVswg-closed set] if $\text{IVcl}(\text{IVint}([\mathcal{M}^-, \mathcal{M}^+])) \subseteq U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq U$ and U is an IVSOs in X .

The complement of above defined ones are Interval-Valued weakly open set, Interval-Valued weakly generalized open set, Interval-Valued strongly generalized semi open set, Interval-Valued semi weakly generalized open set and in short IVWOs, IVwg-open set, IVg*-open set and IVswg-open set respectively.

Definition 3.9 Intersection of all IVWCs (resp. IVwg-closed sets, IVg*-closed sets, IVswg-closed sets) containing $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is called an Interval-Valued weak closure (resp. Interval-Valued weakly generalized closure, Interval-Valued strongly generalized semi closure, Interval-Valued semi weakly generalized closure) of $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ is denoted by $\text{IVwcl}(\mathcal{M})$ (resp. $\text{IVwgcl}(\mathcal{M})$, $\text{IVg}^*\text{cl}(\mathcal{M})$, $\text{IVswgcl}(\mathcal{M})$).

Result 3.10

1. $\text{IVSPCs} \subseteq \text{IVSCs} \subseteq \text{IVPSCs} \subseteq \text{IVCs}$.
2. $\text{IVspcl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq \text{IVscl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq \text{IVpscl}([\mathcal{M}^-, \mathcal{M}^+]) \subseteq \text{IVcl}([\mathcal{M}^-, \mathcal{M}^+])$.



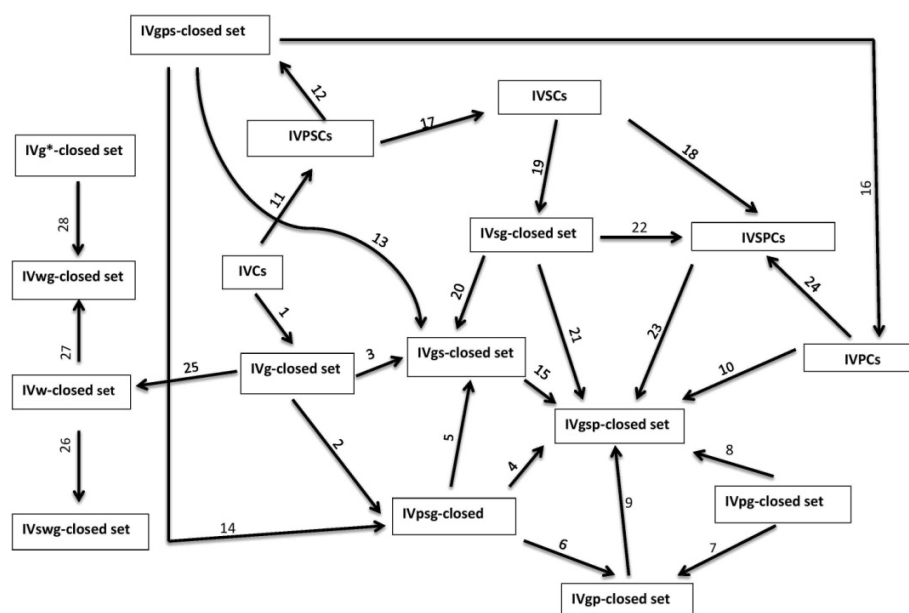


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3. $IVSPOs \subseteq IVSOs \subseteq IVPSOs \subseteq IVOs$.
4. $IVSPCs \subseteq IVPCs$.
5. $IVspcl([\mathcal{M}^-, \mathcal{M}^+]) \subseteq IVpcl([\mathcal{M}^-, \mathcal{M}^+])$.
6. $IVSPOs \subseteq IVPOs$.
7. $IVWCs \subseteq IVCs$ and $IVwcl([\mathcal{M}^-, \mathcal{M}^+]) \subseteq IVcl([\mathcal{M}^-, \mathcal{M}^+])$.

IMPLICATIONS BETWEEN SOME IVC-SETS

Theorem 4.1 The following implications are true but not reversible.



Proof

1. Here, implication **2** is shown.

Let $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in IVS(X)$ be an IVg-closed. Then, $IVcl[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ where U is an IVOs. But, $IVpscl[\mathcal{M}^-, \mathcal{M}^+] \subseteq IVcl[\mathcal{M}^-, \mathcal{M}^+] \subseteq U \Rightarrow IVpscl(\mathcal{M}) \subseteq U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq U$. We can conclude that, $[\mathcal{M}^-, \mathcal{M}^+]$ is an IVpsg-closed. \therefore Every IVg-closed set is an IVpsg-closed set. Implications **3,4,5,6,9,15** are proved alike.

2. Implication **7** is proved here.

$\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+] \in IVS(X)$ be an IVpg-closed set. Then $IVpcl[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ where U is an IVPOs. But, $IVPOs \subseteq IVOs \Rightarrow [\mathcal{M}^-, \mathcal{M}^+] \subseteq U$ where U is an IVOs. Then, $[\mathcal{M}^-, \mathcal{M}^+]$ is an IVgp-closed. Finally, Every IVpg-closed set is an IVgp-closed set. Equivalently, implications **14,20,25,28** are proved.

3. Implication **21** is proved here.

$[\mathcal{M}^-, \mathcal{M}^+] \in IVS(X)$ be an IVsg-closed set. Then, $IVscl[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ whenever $[\mathcal{M}^-, \mathcal{M}^+] \subseteq [U^-, U^+] = U$ where U is an IVSOs. But, $IVspcl(\mathcal{M}) \subseteq IVscl(\mathcal{M})$ and $IVSOs \subseteq IVOs$, which implies $IVspcl(\mathcal{M}) \subseteq IVscl(\mathcal{M}) \subseteq U$. Then, $IVspcl(\mathcal{M}) \subseteq U$, where U is an IVSPOs. Finally, $[\mathcal{M}^-, \mathcal{M}^+]$ is an IVgsp-closed set. \therefore Every IVsg-closed set is an IVgsp-closed set. In addition, implications **8,13,27** are proved.

Other implications are clear-cut. We verify the implications using successful examples.





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Example 4.2 We check implications 1 and 4 are not reversible.

Take $X = \{a, b, c\}$. Then, τ be an IVT gives $\{\emptyset, [\emptyset, \{a\}], [\{a\}, \{a, b\}], [\emptyset, \{c\}], [\{a\}, \{a, c\}],$

$[\{b\}, \{b\}], [\{b\}, \{a, b\}], [\{c\}, X], [\{a\}, X], [\emptyset, \{b\}], [\emptyset, \{a, b\}], [\{a, b\}, \{a, b\}], [\{a, c\}, X], [\{b\}, \{b, c\}], [\{b\}, X], [\emptyset, \{b, c\}], [\emptyset, X],$

$[\{a, b\}, X], [\{b, c\}, X], \tilde{X}$.

$1 \Rightarrow$ IVS $[\{b, c\}, X]$ is an IVg-closed set but not IVCs. Therefore, every IVg-closed set is not an IVCs.

$4 \Rightarrow$ Take an IVS $[\{a\}, \{a\}]$ which is an IVgsp-closed set but not IVpsg-closed set. Therefore, every IVgsp-closed set is not an IVpsg-closed set.

\therefore Implications 1 and 4 are not reversible.

Example 4.3 We check the following implications 6, 7, 8, 10, 24 are not reversible.

$X = \{a, b, c\}$. We get, τ be an IVT as $\{\emptyset, [\emptyset, \{c\}], [\{b\}, \{b\}], [\{b\}, \{b, c\}], [\{a\}, \{a, b\}], [\{a\}, X], [\emptyset, \{b\}], [\emptyset, \{b, c\}], [\{a, b\}, \{a, b\}],$

$[\{a, b\}, X], \tilde{X}$.

- For implication 6, Take $[\emptyset, \{b\}] \in \text{IVS}(X)$ which is an IVgp-closed set but not IVpsg-closed set in X which implies, every IVgp-closed set is not an IVpsg-closed set.
- For implication 7, Now, an IVS $[\{b\}, X]$ is an IVgp-closed set but not IVpg-closed set in $X \Rightarrow$ Every Ivgp-closed set need not be an IVpg-closed set.
- For implication 8, $[\{b, c\}, \{b, c\}]$ be an IVS is taken from the IVTS mentioned above which is an IVgsp-closed set but not IVpg-closed set. \therefore Every IVgsp-closed set need not be an IVpg-closed set.
- For implication 10, Consider $[\{b, c\}, X] \in \text{IVS}(X)$ is an IVgsp-closed set but not an IVPC set in X which implies every IVgsp-closed set is not an IVPC set.
- For implication 24, $[\emptyset, X] \in \text{IVS}(X)$ which is an IVSPCs but not IVPCs in (X, τ) which implies, Every IVSPCs is not an IVPCs.

\therefore 6, 7, 8, 10, 24 these implicationes are not reversible.

Example 4.4 We verify these implications 3, 5, 11, 12, 13, 15, 17, 22 are irreversible.

$X = \{1, 2, 3\}$ with an IVT $\tau = \{\emptyset, [\{3\}, \{1, 3\}], [\{2\}, \{2, 3\}], [\emptyset, \{3\}], [\{2, 3\}, X], [\emptyset, \{2\}], [\emptyset, \{2, 3\}], [\{3\}, X], \tilde{X}$.

$3 \Rightarrow$ Take, $[\{3\}, X]$ from $\text{IVS}(X)$ it is an IVgs-closed set but not IVg-closed set in X .

Therefore, every IVgs-closed set need not be an IVg-closed set.

$5 \Rightarrow$ An $\text{IVS}(X)$ $[\{2\}, \{2\}]$ is an IVgs-closed set but not IVpsg-closed set in (X, τ) .

Therefore, every IVgs-closed set need not be an IVpsg-closed set.

$11 \Rightarrow [\{1\}, \{1\}] \in \text{IVS}(X)$ which is an IVPSCs but not IVCs.

Therefore, every IVPSCs need not be an IVCs.

$12 \Rightarrow$ Using an IVS $[\{1\}, \{1, 2\}]$ is an IVgps-closed set but not IVPSCs is given (X, τ) .

Therefore, every IVgps-closed set need not be an IVPSCs.

$13 \Rightarrow$ Now, consider $[\emptyset, \{1, 3\}] \in \text{IVS}(X)$ which is an IVgs-closed set but not IVgps-closed set in X . Therefore, every IVgs-closed set need not be an IVgps-closed set.

$15 \Rightarrow [\{3\}, \{3\}]$ in (X, τ) is an IVgsp-closed set except instead IVgs-closed set.

Therefore, every IVgsp-closed set need not be an IVgs-closed set.

$17 \Rightarrow [\emptyset, \{2, 3\}] \in \text{IVS}(X)$ is an IVSCs except instead IVPSCs in X .

Therefore, every IVSCs need not be an IVPSCs.

22 Here, $[\{2, 3\}, \{2, 3\}] \in \text{IVS}(X)$ which is an IVSPCs but not IVsg-closed set.

Therefore, every IVSPCs need not be an IVsg-closed set.

Finally, implications 3, 5, 11, 12, 13, 15, 17, 22 cannot be reversed.

Example 4.5 The following example shows that

18. IVSPCs \nRightarrow IVSCs.

19. IVsg-closed set \nRightarrow IVSCs.

21. IVgsp-closed set \nRightarrow IVsg-closed set.

23. IVgsp-closed set \nRightarrow IVSPCs.





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$X = \{1, 2, 3\}$. Then, IVT is $\{\tilde{\emptyset}, M, N, O, P, Q, R, S, \tilde{X}\}$ where $M = [\{1\}, \{1,3\}]$, $N = [\emptyset, \{3\}]$, $O = [\{1\}, \{1,2\}]$, $P = [\emptyset, \{2,3\}]$, $Q = [\{1\}, \{1\}]$, $R = [\{1\}, X]$, $S = [\emptyset, \{2\}]$.

18. To verify this, Take $[\{1,3\}, \{1,3\}] \in \text{IVS}(X)$ it is an IVgsp-closed set but fails as IVSPCs in X which gives every IVgsp-closed set need not be an IVSPCs.

19. To check this, Using an IVS $[\{2\}, X]$ in (X, τ) mentioned above. It is IVSPCs but not IVSCs. Therefore, every IVSPCs need not be an IVSCs.

21. To ensure this, $[\{3\}, \{1,3\}] \in \text{IVS}(X)$ which is an IVsg-closed set except instead IVSCs. Therefore, every IVsg-closed set need not be an IVSCs.

23. To make sure this, Take $[\emptyset, \{1\}] \in \text{IVS}(X)$ which is an IVgsp-closed set but not IVsg-closed set in X . Therefore, every IVgsp-closed set need not be an IVsg-closed set.

Example 4.6

14. IVpsg-closed set \Rightarrow IVgps-closed set.

16. IVPCs \Rightarrow IVgps-closed set.

The above implications is shown by this example. $X = \{1,2,3\}$, Then, $\tau = \{\tilde{\emptyset}, M, N, O, P, Q, R, S, T, \tilde{X}\}$ is an IVT, where $M = [\{1\}, \{1\}]$, $N = [\{2\}, \{2,3\}]$, $O = [\{1,2\}, X]$, $P = [\{3\}, \{3\}]$, $Q = [\{1,3\}, \{1,3\}]$, $R = [\emptyset, \{3\}]$, $S = [\{2,3\}, \{2,3\}]$, $T = [\{1\}, \{1,3\}]$.

14. To verify this, Take $[\emptyset, \{1,3\}] \in \text{IVS}(X)$ which is an IVpsg-closed set but not IVgps-closed set which implies, every IVpsg-closed set need not be an IVgps-closed set.

16. It is checked by $[\emptyset, \{1\}] \in \text{IVS}(X)$ in (X, τ) defined above which is an IVPCs but fails as IVgps-closed set which implies, every IVPCs need not be an IVgps-closed set.

Example 4.7 The implication 20 is not reversible.

by employing this example $X = \{1,2,3\}$ then, $\tau = \{\tilde{\emptyset}, [\{2\}, \{2\}], [\{1,2\}, X], [\{3\}, \{1,3\}], [\emptyset, \{1,3\}], [\{2,3\}, X], [\{2\}, X], \tilde{X}\}$ be an IVT. Let $[\emptyset, \{2,3\}]$ be an IVS(X) which is an IVgs-closed set but not IVsg-closed set which implies, every IVgs-closed set need not be IVsg-closed set.

\therefore Implication 20 is not reversible.

Example 4.8 There is no way to reverse this implication 2.

$X = \{a, b, c\} \Rightarrow \tau = \{\tilde{\emptyset}, [\{c\}, \{c\}], [\{b, c\}, \{b, c\}], \tilde{X}\}$. Using the IVS(X) $[\{b\}, \{b\}]$ we can say that, IVpsg-closed set need not be an IVg-closed set. \therefore Implication 2 can't be reversed.

Example 4.9 The implications 25,26,27 are not reversible.

$X = \{a, b, c\}$ then IVT $\tau = \{\tilde{\emptyset}, [\{c\}, \{c\}], [\{a\}, \{a\}], [\{a, c\}, \{a, c\}], \tilde{X}\}$.

25 \Rightarrow Take $[\emptyset, \{b\}]$ in IVS(X) which is an IVg-closed set but not IVWCs. Then, every IVg-closed need not be an IVWCs.

26 \Rightarrow Take $[\{c\}, X]$ in IVS(X) which is an IVswg-closed set but not IVWCs. Then, every IVswg-closed set need not be an IVWCs.

27 \Rightarrow Take $[\emptyset, \{b, c\}]$ in IVS(X) which is an IVwg-closed set but not IVWCs. Then, every IVwg-closed set need not be an IVWCs.

\therefore Implication 25,26,27 is not reversible.

Example 4.10 To show the implication 28 is not reversible.

Using the successive example, $X = \{a, b, c\}$ with an IVT $\tau = \{\tilde{\emptyset}, [\{a\}, \{a, b\}], [\{c\}, \{c\}], [\{a, c\}, X], [\{a\}, X], [\emptyset, \{c\}], \tilde{X}\}$. Now, Take $[\{a\}, \{a, c\}]$ which is an IVg*-closed set but not an IVwg-closed set. Therefore, Every IVg*-closed set need not be an IVwg-closed set. \therefore Implication 28 is not reversible.

Remark 4.11

1. IVg-closed set \Leftrightarrow IVgps-closed set.





2. IVg-closed set \Leftrightarrow IVsg-closed set.

Example 4.12

1. Working with example 4.9, here we take $[\emptyset, \{a\}]$ is an IVgps-closed set but not IVg-closed set and $[\{a, c\}, X]$ is an IVg-closed set but not an IVgps-closed set.

2. Utilizing an example 4.4, $[\emptyset, \{2\}]$ is an IVsg-closed set not IVg-closed set and $[\{1, 3\}, \{1, 3\}]$ is an IVg-closed set not an IVsg-closed set.

We can conclude that IVg-closed set and IVgps-closed set are independent as like IVg-closed set and IVsg-closed set are independent.

Remark 4.13 $\mathcal{M} = [\mathcal{M}^-, \mathcal{M}^+]$ and $\mathcal{N} = [\mathcal{N}^-, \mathcal{N}^+] \in \text{IVS}(X)$. If both Interval-Valued subsets are neither Interval-Valued semi pre closed nor Interval-Valued semi pre open it may be Interval-Valued semi generalized closed set. The following example is corresponding to this statement.

Example 4.14 Working with example 4.5, The $\text{IVS}(X) [\{3\}, \{3\}]$ is neither IVSOs nor IVSCs but it is an IVsg-closed set.

CONCLUSION

With this piece of work, we constructed some of the Interval-Valued closed sets and some generalizations by applying the notion of Interval-Valued sets, which was proposed by Y. Yao and further researched by J. Kim, Y. B. Jun, and J. G. Lee. Our discussion highlights the implications between them. We provide counterexamples to deduce some irreversible consequences. Examples are also used to examine a few independent characters. Each defined Interval-Valued closed set's interior and closure attributes, together with the characteristics of their generalizations, will be visible in the future.

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Seizing Nutritional Status : The Underexplored Impact of Epilepsy

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ABSTRACT

Epilepsy is a prevalent neurological disorder in children, affecting approximately 0.5% to 1% globally. Malnutrition is a significant concern, especially in those with generalized epilepsy, with incidence rates reaching 25% in this population indicating a need for targeted interventions. A cross-sectional study was conducted among thirty pediatric patients between one month to five years of age with Drug Resistant Epilepsy. Nutritional status was assessed using STRONG_{kids} Nutrition Screening Tool for malnutrition. Neuro imaging and EEG studies were employed to examine seizure activity and brain abnormalities. Statistical analysis included chi-square tests for associations, descriptive statistics for nutrient intake, and correlation coefficients for biomarkers, with significance set at $p < 0.05$ for all comparisons. Thirty children with Drug Resistant Epilepsy were evaluated for nutritional status using STRONG_{kids} Nutrition Screening Tool for malnutrition. Chi-square test showed a significant association between seizures and malnutrition risk ($p < 0.05$). Among thirty children, 40% were at high risk, 33% at medium risk, and 27% at low risk of malnutrition. Parental awareness was low in 65% of cases, significantly linked to higher malnutrition risk ($p < 0.01$). It was found that 60% of children with generalized epilepsy were at high risk for malnutrition, compared to 25% of those with focal epilepsy, indicating a significant association between epilepsy type and nutritional status ($p < 0.05$). Developmental delays were common, with 45% of children showing gross



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motor delays, 30% showing speech delays, and 25% demonstrating cognitive delays. These delays were significantly more frequent in children at high risk of malnutrition ($p < 0.001$). EEG abnormalities were seen in 70% of high-risk children, correlating with malnutrition ($p < 0.05$). Biomarkers, such as low albumin and hemoglobin, strongly correlated with high malnutrition risk ($p < 0.01$). Feeding problems, including poor appetite and swallowing difficulties, were present in 50% of high-risk children. Nutrient intake was analyzed in terms of calories, proteins, carbohydrates, and fats. Around 60% of children failed to meet their calorie ($p < 0.01$), protein ($p < 0.05$), and fat ($p < 0.05$) requirements, while 50% had inadequate carbohydrate intake. This study highlights a critical association between drug-resistant epilepsy and malnutrition among epileptic children, emphasizing the need for targeted nutritional interventions to improve health outcomes and developmental trajectories in this vulnerable population.

Keywords: Epilepsy, Malnutrition, Pediatric, Nutritional status

INTRODUCTION

Epilepsy is one of the most common neurological disorders in children, with a global prevalence of approximately 0.5% to 1% [1,2]. While epilepsy is primarily managed by pharmacological interventions, the disorder is often linked to various comorbidities, one of the most significant being malnutrition [3,4]. Children with generalized epilepsy are particularly susceptible, with reports showing up to 25% of this population experiencing some form of malnutrition [5]. The relationship between epilepsy and malnutrition is multifaceted, influenced by factors such as the frequency of seizures, the side effects of antiepileptic drugs (AEDs), and the broader metabolic impacts of the disorder [6]. Malnutrition not only hinders the physical growth of children but also negatively affects their cognitive and motor development, leading to a diminished quality of life [7,8]. Despite these concerns, the relationship between epilepsy and nutritional status remains underexplored [9]. Given the complexities of managing epilepsy, especially drug-resistant epilepsy (DRE), nutritional assessment and interventions may provide a pathway to improving overall health outcomes [10]. This study aims to explore the prevalence of malnutrition in children with drug-resistant epilepsy and to analyze its associations with seizure activity, neuro developmental delays, and parental awareness [11].

METHODOLOGY

A cross-sectional study was conducted in a tertiary care hospital among thirty pediatric patients diagnosed with drug-resistant epilepsy. The inclusion criteria were children aged one month to five years, with a confirmed diagnosis of epilepsy that did not respond to at least two appropriately chosen and administered antiepileptic drugs. Exclusion criteria included children with metabolic or genetic disorders unrelated to epilepsy. Nutritional status was assessed using the STRONGkids Nutrition Screening Tool, which categorizes children into low, medium, and high-risk groups for malnutrition based on clinical indicators such as weight loss, food intake, and clinical appearance. Caloric, protein, fat, and carbohydrate intake were measured through 24-hour dietary recalls and analyzed using standardized nutritional software. To explore the neurological impact, all children underwent neuroimaging (MRI or CT) and EEG studies to detect abnormalities. Neuro developmental delays were assessed using standardized developmental screening tools, with a focus on motor, cognitive, and speech domains. The collected data were analyzed using descriptive statistics for nutritional intake (calories, proteins, fats, carbohydrates). Chi-square tests were used to evaluate the association between malnutrition and seizure characteristics (e.g., type of epilepsy). Pearson correlation coefficients were computed to assess the relationship between biomarkers (e.g., hemoglobin and albumin) and malnutrition risk. Significance was set at $p < 0.05$ for all comparisons. The study was approved by the Institutional Ethical Committee of Sri Ramachandra Institute of Higher Education and Research, Porur, Chennai. (REF NO: IEC/24MAR/185/09). The study was registered in Clinical Trial Registry India CTRI/2024/05/067973.





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RESULTS

Demographic and Clinical Characteristics

A total of thirty children with drug-resistant epilepsy participated in the study. Of these, 60% had generalized epilepsy, and the remaining 40% had focal epilepsy [Figure 1]. The majority of children (65%) came from families with low parental awareness regarding the nutritional and developmental needs of children with epilepsy.

Nutritional Risk Assessment

The STRONGkids screening tool revealed that 40% of the children were at high risk for malnutrition, 33% were at medium risk, and 27% were at low risk [Figure 2]. The chi-square test showed a significant association between the type of epilepsy and malnutrition risk ($p < 0.05$), with 60% of children with generalized epilepsy at high risk compared to 25% of those with focal epilepsy.

Developmental Delays

Developmental delays were prevalent, particularly in children at high risk of malnutrition. Gross motor delays were observed in 45% of children, speech delays in 30%, and cognitive delays in 25% [Figure 3]. The occurrence of these delays was significantly higher in children at high risk of malnutrition ($p < 0.001$), demonstrating a strong link between poor nutritional status and impaired neurodevelopment.

EEG and Neuroimaging Findings

EEG abnormalities, including frequent seizure spikes and background slowing, were present in 70% of children at high risk for malnutrition, further supporting the association between nutritional status and the severity of seizure activity ($p < 0.05$). Brain imaging also revealed structural abnormalities in a significant proportion of children, including cortical atrophy and hippocampal sclerosis.

Nutrient Intake and Biomarkers

The analysis of dietary intake revealed significant deficiencies in calorie ($p < 0.01$), protein ($p < 0.05$), and fat intake ($p < 0.05$) in 60% of children, while 50% had inadequate carbohydrate intake. Biomarkers such as low hemoglobin and albumin levels were significantly correlated with high malnutrition risk ($p < 0.01$). Feeding problems, including poor appetite and swallowing difficulties, were reported in 50% of high-risk children, further compounding their nutritional deficits.

Parental Awareness

Low parental awareness (65%) was significantly linked to a higher risk of malnutrition in their children ($p < 0.01$). This finding underscores the importance of educating caregivers about the nutritional needs of children with epilepsy to prevent malnutrition.

DISCUSSION

The findings from this study highlight the critical association between drug-resistant epilepsy and malnutrition in pediatric patients [12,13]. Children with generalized epilepsy are particularly vulnerable to malnutrition, likely due to more frequent seizures and the greater metabolic demands placed on the body [14]. This vulnerability is compounded by the side effects of antiepileptic drugs, which can lead to reduced appetite and feeding difficulties, as observed in the study [15]. The association between developmental delays and malnutrition suggests that poor nutritional status not only affects physical growth but also hampers cognitive and motor development [16,17]. These delays could further exacerbate the challenges faced by children with epilepsy, limiting their ability to participate in daily activities and social interactions [18]. The EEG and neuroimaging findings corroborate the hypothesis that malnutrition exacerbates the severity of epilepsy, possibly through metabolic dysregulation or impaired brain development [19, 20]. The role of parental awareness in preventing malnutrition cannot be overstated [21]. Many



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caregivers may not be aware of the heightened nutritional needs of children with epilepsy, leading to inadequate feeding practices and delayed intervention [22]. Nutritional counseling should be an integral part of the care plan for children with epilepsy to ensure optimal growth and development [23].

CONCLUSION

This study underscores the significant impact of drug-resistant epilepsy on the nutritional status of children, with profound implications for their overall health and development. The high prevalence of malnutrition among children with generalized epilepsy, in particular, calls for targeted nutritional interventions. Parental education and awareness programs, along with regular nutritional assessments, should be incorporated into epilepsy management protocols to improve outcomes for this vulnerable population. Further research is needed to explore the long-term effects of nutritional interventions on seizure control and neuro developmental outcomes in children with epilepsy.

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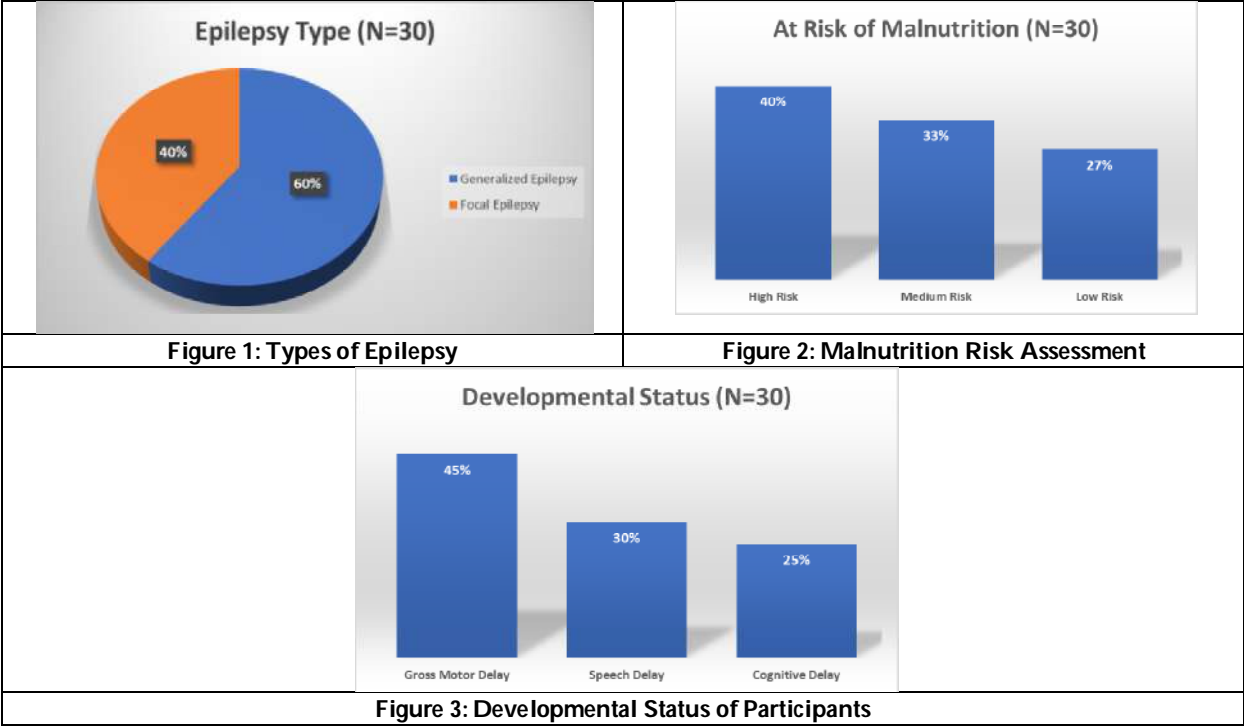
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A Novel Methodology for Assessing Teachers' Perception of Students' Blended Assessment

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ABSTRACT

In the present age of technology, innovation in the field of assessment practices is a very important aspect and a key component in the teaching-learning process. Blended assessment is the need of the hour so that the students can get the credits from offline as well as online assessment practices. The existing study intended to examine the teachers' perception of the concept of Blended assessment and to identify the various types of blended assessment practices and different online assessment platforms used by the teachers to make blended assessment effective and feasible. Additionally, this study also anticipated identifying the number of resources available to execute the Blended Assessment practices and examining the challenges faced by teachers. Moreover, it suggests a mechanism for improving Blended assessment during the teaching-learning process. The current study will help to know about the various blended assessment methods used by the teachers in the present scenario and several challenges faced by them during the assessment of students in Blended mode. For this purpose, the investigator gets the data from the teachers teaching at Central University of Jammu, District Samba of UT J&K with the help of a semi-structured questionnaire. Additionally, this study will provide Suggestions for the betterment of Blended assessment in teaching-learning in the future and for making assessment an enjoyable process for learners.

Keywords: Blended assessment, Assessment platforms, Innovation, teachers' perception, credits





INTRODUCTION

Technological awareness among teachers is one of the major issues in the existing education system. Teachers in our educational institutions are not prominently using technological assessment practices in the teaching-learning process. Many researches have established that technology can produce a cooperative and attractive learning environment that has a constructive effect on the progress of the students[1]. The use of technology in the assessment of students can do wonders in relation to their achievement. Assessment is an important aspect of teaching-learning to know to what extent our learning outcomes are achieved or how well the teacher conveys information to students. The teacher can use any type of Assessment i.e., formal or informal to gather information about the achievement of students[2]. The Quality Assurance Agency (QAA, 2006, p.4) describes assessment as “any processes that appraise an individual's knowledge, understanding, abilities or skills”. Assessment is the continuing process of developing strong and computable probable results of student learning. It also ensures that students have numerous opportunities to achieve the learning outcomes set at the begging of teaching. It is analytically collecting, analysing, and interpreting suggestions to know how well students had achieved the learning outcomes, and this will help in improving students’ learning[3]. Assessment means “activities designed primarily to foster student learning.” So, it is clear that planning and using different assessment practices is a significant part of professional development of teachers[4]. Earlier teachers used the paper-pencil assessment which was boring and time-consuming. Now, in this era of technology, the incorporation of technology into the teaching-learning process and in the assessment of students has changed the scenario of teaching-learning in a positive manner[2].

Blended means mixed and assessment means the use of variation in techniques to measure the achievement of the students. Blended assessment is the combination of Online and offline methods of assessing the students. It is the mixture of traditional and modern assessment practices of assessing the students by making assessments as a part of learning in a joyful manner. In National Educational Policy 2020, it is also mentioned that General Education Council (GEC) will set up facilitative norms for credit transfer[5]. It is also a form of blended assessment. Students with their offline classes can earn credits online which will be directly transferred to their academic course. Blended learning permits educationalists to mix elements of traditional face-to-face instruction with online learning systems and is generally adopted in higher education for varied purposes by using varied execution strategies[6]. In Blended learning atmosphere, assessment in Blended mode is most commonly used which enriches the blended learning environment in a playful manner. Online assessment of the learners is popular since many years. Though, despite of the usage of online assessment in educational settings, many studies have informed about the barriers which affect the practice. The shift from the physical classroom-based traditional assessment to a virtual one doesn't fulfill the requirements of assessment[4]. Thus, combination of online and offline strategies of assessment can be proved beneficial in the coming era of technological assessment. The proper use of blended assessment strategies can make the learning effective and fruitful. In this era of technology if teacher use a varied amount of assessment practices in teaching learning process, it can enhance the achievement level as well as the interest of the students in the learning process. In this work we examine about the awareness of teachers about Blended learning strategies and their level of proficiency in the new technological inventions in the assessment practices. The investigator also highlights the various challenges faced by the teachers during blended assessment.

The major contributions are summarized as follows

- I. We present an approach for the evaluation for the awareness of the instructors about the use of blended assessment in the teaching learning process.
- II. We designed a tool to evaluate the perception of teachers on blended assessment.
- III. Our research proposed some viable solutions for the instructors via the ICT (Information and Communication Technology) in the assessment of the students.
- IV. The existing paper provides suggestions for the betterment of Blended assessment practices in the learning environment



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- V. The article highlights various open research issues faced by the instructors and suggested futures perspectives to overcome those problems. Rest of the article is organized as follows: Section II present some of the approaches related to our work. In section III, systematic methodology of the proposed assessment method is discussed. Section IV represents the result analysis and in section V challenges faced by the instructors and few suggestions to overcome those challenges are given. In Section VI conclusions are discussed as depicted in Figure 2.

RELATED WORK

Janier & Shafie, (2009)[2] in their research study highlighted that by using blended assessment strategies for managing the classroom environment the teacher can easily mark the scripts within no time and can produce results immediately. It will help the teacher to use his/her time efficiently. Yukselturk & Curaoglu(2010)[3] revealed that most of the issues with online education have been resolved through time, and fresh approaches have been created for a better learning environment. One of the key issues with online education is the assessment component of the curriculum, which is still a challenging issue. Despite the numerous comments and studies on the benefits of online learning, there have been few evaluations. This presents a challenge to educators because they are unsure of how to implement assessment in online courses and how to use computer-mediated tools to track and inform performance and progress. Yeop et al., (2016)[7] have pointed out that because of tremendous rise in the relevance of technology in society, many educators and academics think it is essential for educators to use technology as a tool to enhance students' learning towards educational goals. The World Wide Web also enables educators to take the classroom outside of the four walls of the classroom and reach students throughout the globe. Dziuban et al., (2018)[8] initiated that blending improves success rates for both minority and non-minority students and maintains or expands access for the majority of student cohorts. Additionally, blended learning holds the top spot when students voice their opinions on the efficacy of their learning settings. Zhang et al., 2021[9] discussed the COVID-19 pandemic has caused a switch from face-to-face to online education and evaluation. Even after the pandemic, this change may have a long-lasting effect on classroom-based evaluation. Berga et al., (2021)[6] revealed that advanced and flexible learning options are encouraged by blended learning (BL). It helps in encouraging the continuous application and assessment of blended learning as a pedagogical strategy. Heilporn et al., (2021)[10] proposed that when possible, the methods teachers employed to encourage student participation in synchronous and asynchronous modes of BL were related to the student engagement parameters. In IASET, (2021)[11] it was recommended that blended Teaching is the ability of connecting online materials to actual classes for making teaching more effective.

METHODOLOGY**Research questions**

1. Are the teachers aware of the concept of Blended assessment?
2. How frequently the teachers are using the various types of blended assessment practices in classroom?
3. what are the different online assessment platforms used by the teachers to make blended assessment effective and feasible?
4. Are sufficient number of resources available to execute the Blended Assessment practices?
5. What are the challenges faced by the teachers during blended assessment?
6. What mechanism the investigator will suggest for improving Blended assessment practices on the basis of present study?

Objectives

1. To examine the awareness of teachers about the concept of Blended assessment.
2. To identify the various types of blended assessment practices.



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3. To identify different online assessment platforms used by the teachers to make blended assessment effective and feasible.
4. To identify the number of resources available to execute the Blended Assessment practices.
5. To examine the challenges faced by the teachers during Blended assessment.
6. To suggest the mechanism for improving Blended assessment during the teaching learning process.

Delimitation of the study

The study was only confined to the faculty members from Central University of Jammu.

Population of the study

In the present study all the Teachers teaching in Central University of Jammu, District Samba of UT of Jammu and Kashmir constituted the Population.

Tool used

A self-Prepared Semi- Structured Questionnaire was used for the collection of data. For this tool content validity and face validity have been established by the investigator in which the questionnaire was consulted with experts and the senior research scholars.

Selection of the sample

For the present study, the investigators shared the self-prepared Semi- Structured questionnaire with all the teachers teaching in Central University of Jammu. Out of 118 teachers, 30 teachers filled the Questionnaire and reverted it back. Thus 30 teachers teaching in Central University of Jammu constituted the sample of the study.

Statistical technique used

- Manifested Content Analysis
- The percentage Analysis technique was used for the analysis of data.

RESULT ANALYSIS

Table 1 shows that the percentage of teachers who are not aware of Blended Assessment is significantly lower (10%) than the percentage of teachers who are aware of Blended assessments. From the above table, it may be inferred that 90% of teachers are aware of the concept of Blended Assessment. Table 2 depicts that the Percentage of use of the Summative type of Blended assessment used by the teachers is negligible (0%), However, 33.33 % of teachers are using both types of Blended assessment, 53.33% of teachers are using the Formative type of Blended assessment and among these teachers, 13.33% teachers are those who are not using Blended Assessment strategies in their classrooms. From the above table, it can be inferred that most teachers use a Formative type of assessment in their Blended assessment strategies. Table 3 demonstrates that the percentage of teachers who never used (6.67%) or those who are using less (30%) blended assessment in the classroom is comparatively low than those teachers who often (43.33%) or very often (20%) using it in the classroom. It may be inferred that most of the teachers often using Blended assessment in the classrooms. From Table 4, it may be inferred that majority of teachers are using Whats App (40%) and Google meet (40%) as an online platform for assessing the students. 36.67% teachers are using Google form for assessment purpose, 23.33% teachers are using Gmail, 20% teachers are using Moodle and Quizzes, 13.33% teachers are using Zoom and Kahoot. Similarly, 6.67% teachers are using Poll Everywhere and Google Classroom, 3.33% teachers are using Mentimeter, Crowd signal and Quiz maker. However, 10% are those teachers who are not using any online assessment platform. It may be inferred that majority of the teachers are using various online platforms for assessing the students in varied ways. Table 5 shows that 76.67% of teachers found Blended assessment effective and 23.33% of teachers doesn't find it effective. Those teachers who found Blended assessment effective justified their reason that Blended assessment has the potential to assess the learning beyond knowledge and understanding level and give scope for assessment of higher order thinking skills along with other domains of



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learning. It also determines whether the goals of teaching are being met. Another significant reason given by the teachers was Blended Assessment makes the learning effective and help the students to participate in learning. It also saves time and helps in 360' assessment of students. It also gives exposure to students and teachers for alternative methods of assessment. Blended assessment enhances the digital literacy and student participate in joyful mood. They also mentioned that if Blended assessment is utilised efficiently, it will enhance the horizons of assessment because it is time saving and unbiased in nature. Teachers can get real time and get instant feedback from the learners by using various learning management systems. It is easy to evaluate since results can be generated automatically. Percentage of teachers who found Blended assessment not effective (23.33%) revealed that most of them didn't ever used Blended assessment and they recommend that only offline assessment is better. So, it can be inferred from the above table that most of the teachers found Blended assessment effective. Table 6 represents the percentage of teachers who found blended assessment not feasible(20%) and those who are not sure about the feasibility of Blended assessment (6.67%) is comparatively less than those teachers who found blended assessment feasible (73.33%). Table7 illustrates that the most of the teachers (50%) admits that there is availability of resources for blended assessment. Few teachers revealed that sufficient number of resources are not available (33.33%)for the execution of Blended assessment and some of the were not sure about the availability of resources(16.33%).

Some of the teachers explained that there is need for improvement in quality and quantity of resources because there are limited resources available and still there is requirement of resources. A number of resources can be availed according to need and purpose. They revealed that for proper execution of context more resources are needed and varies from place to place. They suggested that there are many platforms available but proper selection of Technological and Pedagogical content Knowledge (TPAK) is required for the accomplishment of objectives framed and for that proper training of teachers is required. Table 8represents that the percentage of teachers who doesn't have sufficient level of Training is significantly lower (40%) than the percentage of teachers who have sufficient level of Training (60%). From the above table, it may be inferred that 60% of teachers have sufficient level of training for Blended Assessment. Teachers further explained that continuous learning is always a key to keep oneself updated, so more training about new technologies and recent advancements is always required to keep up with the latest resources. For this, workshops or teacher training programmes that will give hands on experience of abstract concepts of applications, platforms and tools should be organised from time to time. More training programmes should focus on assessment of learning. Some teachers emphasized that if institutions try to conduct workshops, seminars and capacity building programmes in offline mode, it will supplement the skills of the teachers. Table 9shows that the percentage of teachers who are not in favour of statement that there is a transparency in Blended assessment is significantly less(33.33%) than the teachers who are in favour(66.67%). Teachers (66.67%)clarified that Blended assessment is criteria based which well in advance are required to be communicated to the assesses. It gives the scope of remedial action by enhancing the accessibility of performance to all the learners. Blended assessment provides flexibility of learning and improves students' achievement. It cross checks the traditional mode of knowledge. They explained that most of the means of Blended assessment are accessible to teachers, students and even publicly visible. According to them Blended assessment is objective and transparent in nature and doesn't include personal bias because chances of manipulation are less. It also helps the learners to know their level of performance at once with automatic feedback. Some teachers (33.33%) pointed out that in blended assessment there may be the chances of copying and assessing students is not a blind process. So, while using Blended assessment teacher need to assess the students by asking questions based on higher order thinking skills (HOTS). The results shown in Table 10, clearly highlight the superiority of the proposed approach on particularly on all the selected factors such as mode, teacher awareness of the blended assessment, type of assessment and , etc. Moreover, our approach is very effective in overall assessment of the teacher's perception about blended-based students evaluation.





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CONCLUSIONS

In this study the researcher tried to provide the detailed overview about the concept of blended assessment, why blended assessment is important and perspectives of teachers from Central University of Jammu regarding Blended assessment. Here investigator tried to highlight the various challenges faced by teachers during blended assessment and had given the possible solutions(suggestions) with which implementing Blended assessment in the institutions can be possible. In conclusion it can be interpreted that in blended assessment there is lots of challenges faced by the teachers now a days, teachers can cope up with these challenges by upgrading their technological skills. During this type of assessment there should be proper planning on the part of teachers. Teachers should keep in mind that assessment should be learner centered, designed according to the needs of the learners, promotes collaboration and encourage students to develop their skills and how they can give their feedback with proper technological support[1]. on the basis of results and suggestions the researcher proposes that with the advancement in technology in every field of life, it should be incorporated in the field of assessment as well, so that students and teachers can enjoy the teaching learning process and their achievement

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Table 1: Awareness of Blended Assessment

S.No.	Response	No. of teachers	Percentage of Teachers
1	Yes	27	90
2	No	3	10

Table 2: Type of Assessment used while implementing Blended Assessment

S.No.	Response	Number of teachers	Percentage
1	Formative	16	53.33
2	Summative	0	0
3	Both	10	33.33
4	Not used	4	13.33

Table 3: Frequency (Use of Blended Assessment in Classroom)

S.No.	Frequency	Never	Less	Often	Very Often
1	Number	2	9	13	6
2	Percentage	6.67%	30%	43.33%	20

Table 4: Online Platform Used

S.No.	Online Platform	Number	Percentage
1	WhatsApp	12	40
2	Google Form	11	36.67
3	Kahoot	4	13.33
4	Gmail	7	23.33
5	Moodle	6	20
6	Google Meet	12	40
7	Zoom	4	13.33
8	Quizzes	6	20
9	Poll everywhere	2	6.67
10	Google Classroom	2	6.67
11	Mentimeter	1	3.33
12	Crowd Signal	1	3.33
13	Quiz Maker	1	3.33
14	Not Used	3	10

Table 5: Effectiveness of Blended Assessment

S.No.	Response	Number of responses	Percentage
1	Effective	23	76.67
2	Not Effective	7	23.33

Table 6: Feasibility of Blended Assessment

S.No.	Response	Number of Responses	Percentage of Responses
1	Yes	22	73.33
2	No	6	20
3	Not Sure	2	6.67





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Table 7: Availability of Resources

S.No.	Response	Number of Responses	Percentage of Responses
1	Yes	15	50
2	No	10	33.33
3	Not Sure	5	16.33

Table 8: Sufficient Level of Training

S.No.	Response	Number of Responses	Percentage of Responses
1	Yes	18	60
2	No	12	40

Table 9: Transparency in Evaluation

S.No.	Response	Number of Responses	Percentage of Responses
1	Yes	20	66.67
2	No	10	33.33

Table 10: A comparative analysis of proposed work with the existing studies

Year	Author(s)	Mode	Teacher's Awareness of Blended Assessment	Type of Assessment	Online platforms	Effectiveness of Blended Assessment	Feasibility of Blended Assessment	Teacher's Sufficient level of Training
2009	Janier & Shafie[2]	Blended	✓	✓	✓	×	×	×
2010	Yukselturk&Curaoglu[3]	Blended	×	✓	✓	✓	×	×
2016	Yeop et.al.[7]	Blended	×	×	✓	×	×	×
2018	Dziuban et.al.[8]	Blended	✓	×	✓	✓	×	×
2021	Zhang et.al.[9]	Online	×	✓	✓	×	×	×
2021	Berga et.al.[6]	Blended	×	✓	✓	×	×	×
2021	Heilporn et.al.[10]	Blended	×	✓	✓	×	×	×
2021	iaset[11]	Blended	×	✓	✓	×	×	×
2023	Our approach	Blended	✓	✓	✓	✓	✓	✓

Table 11: Challenges and Suggestions

CHALLENGES FACED BY TEACHERS IN BLENDED ASSESSMENT	SUGGESTIONS FOR PROPER IMPLEMENTATION OF BLENDED ASSESSMENT IN FUTURE:
<p>1) Learner's Readiness: The most important challenge which teachers are facing during Blended assessment is the readiness of the learners to participate effectively and wholeheartedly in the assessment process.</p>	<ul style="list-style-type: none"> ➤ Teachers should gain the confidence of the students by making the learning effective and joyful by using various assessment platforms. ➤ Teacher should use creative tasks while planning or creating Blended assessment and he/ she should plan according to the cognitive level of the students. ➤ There should be involvement of every student in the classroom activities so that no one lag behind.





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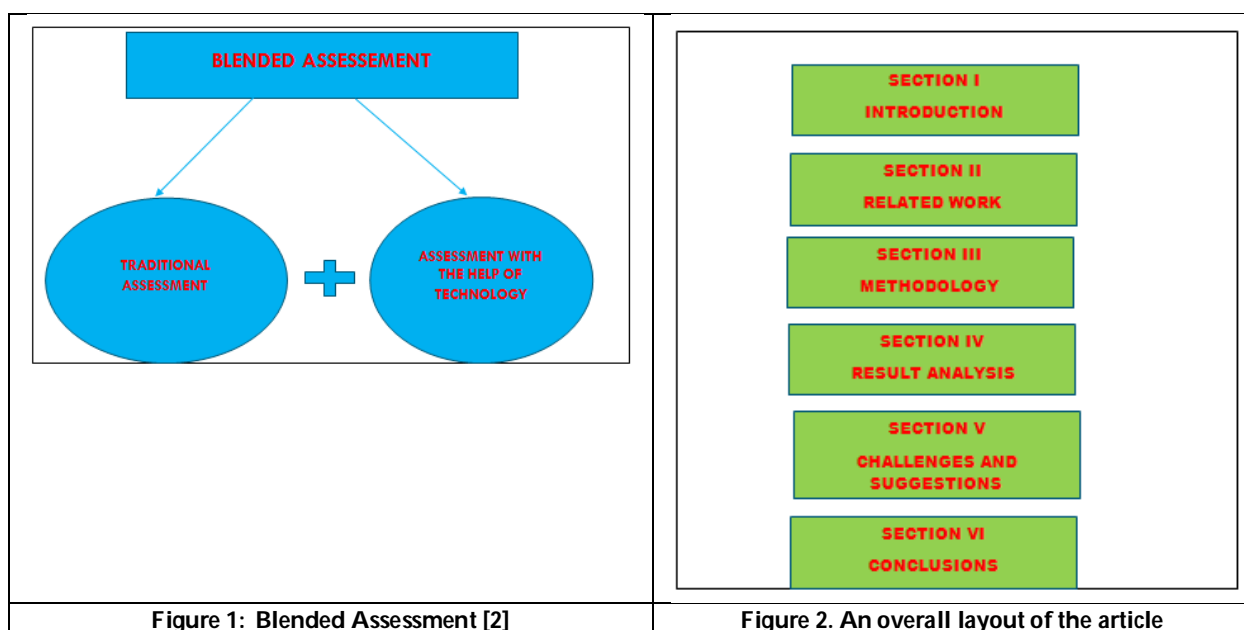
<p>2) Lack of Resources: Lack of dedicated resources mainly internet and electronic resources(electricity etc.) is also one of the major challenges for executing Blended assessment.</p>	<ul style="list-style-type: none"> ➤ Sufficient and dedicated resources can be allocated for the proper execution of blended assessment. ➤ For stable internet connectivity and other resources there should be proper coordination between administration, teachers and students as well.
<p>3) Lack of training: Lack of training of teachers as well as students is also an important challenge, teachers without proper training are unable to explain students that how particular mode works.</p>	<ul style="list-style-type: none"> ➤ Training by good experts for both teachers and students should be provided. ➤ More workshops on blended assessment and various online platforms should be organised by various institutions in order to make the teachers as well as students techno friendly. ➤ Training at pre- service and in-service level should be provided to the teachers to overcome the future technology related issues.
<p>4) Time consuming: Blended assessment is time consuming because students and teachers are not well trained as well as aware about the proper use of this type of assessment. So, it takes lots of time to perform the blended assessment activities.</p>	<ul style="list-style-type: none"> ➤ Training sessions for students and teachers can be organised so that they can effectively use technological interventions in the assessment. ➤ If teachers are well aware of different platforms of assessment, they can assess the students quickly and within no time. Assessment results with technology can be generated easily and automatically with technology(which is not possible by doing it manually)
<p>5) Infrastructural challenges: Buying the right classroom technology is also a challenge in Blended assessment. Infrastructural challenges in the form of devices, network, training issues etc. are generally faced by the teachers during their assessment.</p>	<ul style="list-style-type: none"> ➤ Getting new infrastructural resources is a time-consuming process. So existing resources should be improved to enhance the level of learning among students. ➤ ICT devices should be regularly updated which can reduces the chances of malfunctioning during assessment. ➤ There should be support from administration to reduce the technological and infrastructural glitches.
<p>6) Digital gap: The major challenge in blended assessment is digital gap. People living in cities and with well-furnished resources can easily execute the technological practices rather than people living in villages or far-flung areas. Sometimes it is very difficult to keep the track record of both online and offline assessments.</p>	<ul style="list-style-type: none"> ➤ There should be digital inclusion of all the students and teachers. ➤ There should be smart classroom with every teacher to reduce the gap among the students. ➤ There should be gradual shift from previous to new.
<p>7) Network issues: Network connectivity is the most important challenge faced by teachers as well as</p>	<ul style="list-style-type: none"> ➤ Issues of connectivity can be resolved by providing WLAN in every institution.





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students in Blended assessment. Sometimes even bright students are not able to complete their assessment on time task online because of poor internet connectivity.	<ul style="list-style-type: none"> ➤ Administration and govt. can do positive initiatives for the betterment of internet facilities. ➤ Asynchronous assessment methods can be used to reduce the poor connectivity gaps.
8) Clarity of concept: Sometimes students doesn't have the clarity of the concept of assessment on particular platform, so they do not take it seriously and take it as a burden that they have to carry with them.	<ul style="list-style-type: none"> ➤ There should be exposure to collaborative form of assessment to students and teachers. ➤ Teachers should use questions that can boost higher order thinking skills (HOTS) among students.
9) Unsatisfactory response: Sometimes students thinks that Blended assessment is not effective since they do not have proper awareness of this type of assessment. Maintaining students' attention is also an important task for teachers.	<ul style="list-style-type: none"> ➤ Teachers should gain confidence of students by making the assessment as a playful and joyful activity in a friendly manner. ➤ Good relationship and mutual understanding between the teachers and students can enhance the level of response of students, so there should be friendly relationship between students and teachers.
10) Maintaining transparency: Maintaining transparency is the major issue in blended assessment. Sometimes students can complete the assignments with the help of Google in online assessment. There are many applications available which can complete the task in minutes by using technology. Here is the main issue of transparency where students can smartly bypass the very purpose of assessment.	<ul style="list-style-type: none"> ➤ Use of multiple types of assessment strategies can enhance the transparency in assessment. ➤ With the use of technological platforms of assessment, results can be automatically generated with the time frame and in blended learning set up teacher can tally their online performance in offline setting also. ➤ In synchronous assessment chances of transparency in assessment are higher.



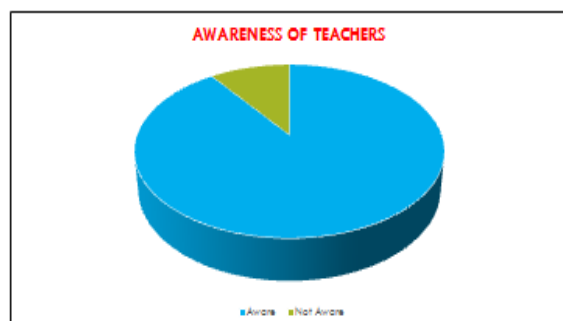


Figure 3: Percentage analysis of awareness of teacher about Blended Analysis

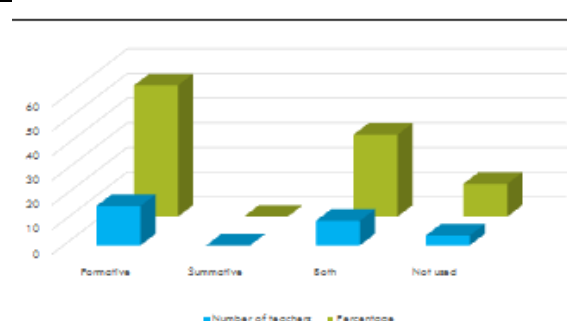


Figure 4: A comparative analysis of type of assessment used by the teachers

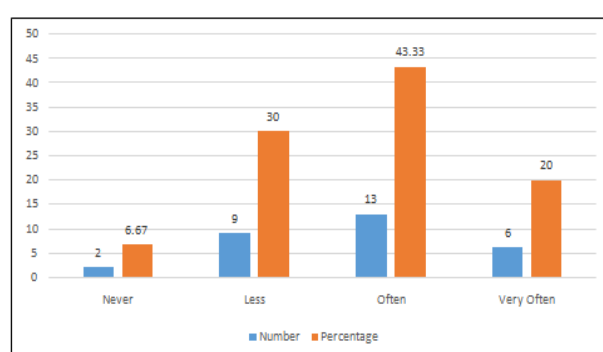


Figure 5: An analysis of frequency of Blended assessment practices used inside the classroom

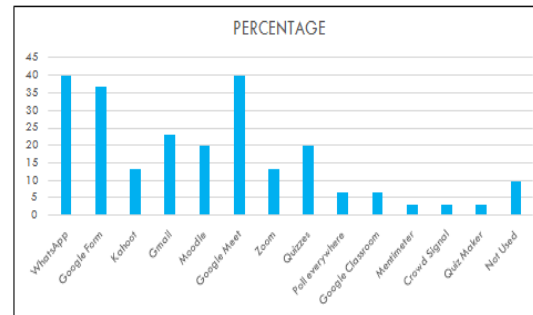


Figure 6: A comparative analysis of online platform used by the teachers for blended assessment

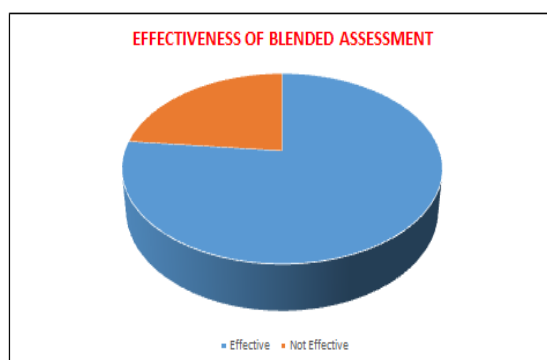


Figure 7: A Percentage analysis of Effectiveness of blended assessment

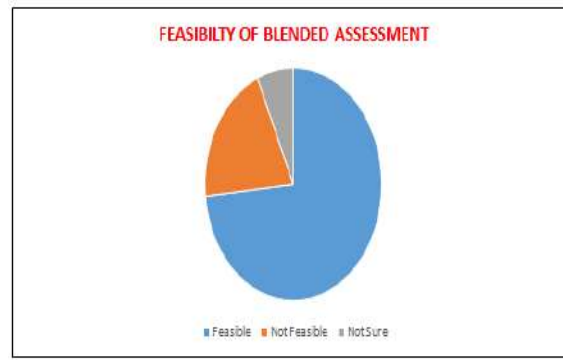


Figure 8: An analysis of feasibility of Blended assessment practices





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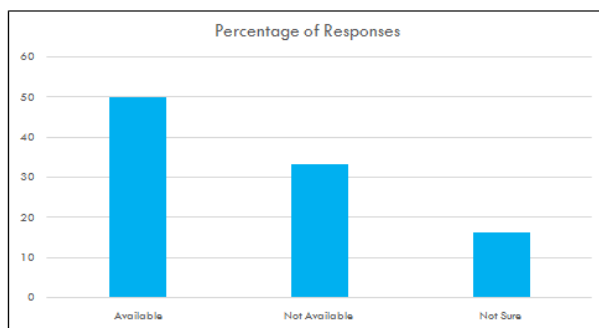


Figure 9: An analysis of Availability of Resources required for blended assessment

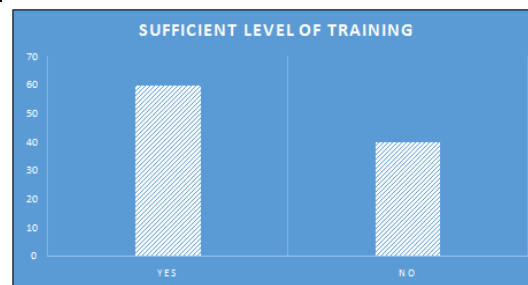


Figure 10: Analysis of percentage of teachers having sufficient level of training

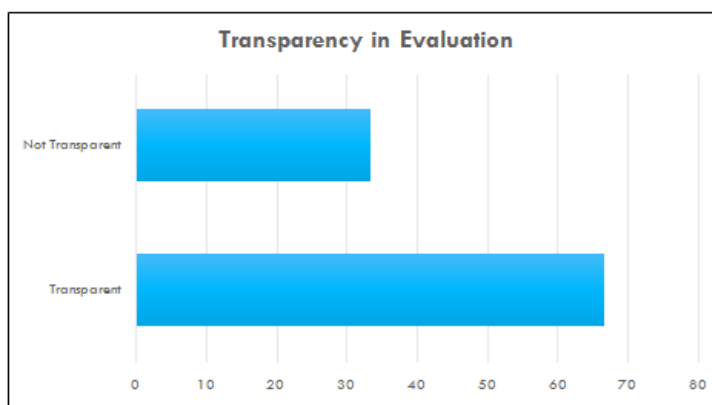


Figure 11: An analysis of perception of teachers about transparency in Blended assessment





***In vitro* Evaluation of Antioxidant and Anti-Inflammatory Activities of Date Palm Fruit Extract : Potential Therapeutic Implications**

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ABSTRACT

The Date Palm (*Phoenix dactylifera*) is a widely consumed fruit known for its nutritional and medicinal properties. This study investigates the antioxidant and anti-inflammatory potential of Date Palm Fruit Extract (DPFE), with a focus on its therapeutic application in chronic inflammatory diseases. DPFE was extracted using an aqueous method, followed by phytochemical screening to identify bioactive compounds. The antioxidant activity of the extract was evaluated through in vitro assays, including superoxide, hydroxy, and nitric oxide radical scavenging, and reducing power. The anti-inflammatory effects were assessed by protein denaturation and membrane stabilization assays using human red blood cells (HRBC). Phytochemical analysis revealed the presence of alkaloids, carbohydrates, flavonoids, and tannins in DPFE. In antioxidant assays, DPFE exhibited significant free radical scavenging activity, with the highest scavenging observed at 500 µg/ml for superoxide (86%), hydroxy (79.62%), and nitric oxide





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(101.01%) radicals. The IC₅₀ values for scavenging activities were 9 µg/ml (superoxide), 17.85 µg/ml (hydroxy), and 10.20 µg/ml (nitric oxide). Additionally, DPFE showed 70.30% inhibition of albumin denaturation and 79.52% protection in the HRBC membrane stabilization assay at 500 µg/ml. The results demonstrate that DPFE possesses potent antioxidant and anti-inflammatory activities, with significant potential for therapeutic use in managing oxidative stress and inflammation. Bioactive compounds such as flavonoids and tannins may contribute to these effects. Further studies are needed to isolate and characterize the active compounds and explore the clinical applications of DPFE in inflammatory diseases.

Keywords: Date Palm Fruit Extract, Antioxidant Activity, Anti-inflammatory Activity, *In Vitro* Studies, Phytochemicals, Radical Scavenging Activity, Protein Denaturation.

INTRODUCTION

Chronic inflammatory diseases are a major global healthcare challenge, contributing to the pathogenesis of numerous life-threatening conditions such as cardiovascular diseases, cancer, metabolic syndrome, neurodegenerative disorders, and autoimmune diseases. These diseases are often characterized by persistent low-grade inflammation, which disrupts normal cellular function and accelerates degenerative processes in tissues. While traditional anti-inflammatory therapies, including nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, provide symptom relief, they are frequently associated with undesirable side effects, particularly when used over extended periods. This has sparked increasing interest in finding safer, natural alternatives that can modulate inflammation effectively without compromising patient health [1-2]. Natural products, especially those derived from plants, have gained significant attention for their potential therapeutic properties in managing inflammation-related diseases. Among these, the date palm (*Phoenix dactylifera*) stands out due to its rich composition of bioactive compounds, including antioxidants, flavonoids, and phenolic acids, which are known to exhibit both anti-inflammatory and antioxidant activities [3]. In Middle Eastern and North African cultures, date palm fruit has long been regarded as both a dietary staple and a natural remedy for a wide range of ailments. Emerging research has begun to substantiate these traditional uses, revealing that date palm fruit possesses a unique phytochemical profile that may influence the molecular pathways involved in inflammation and oxidative stress [4].

The therapeutic potential of date palm fruit is primarily attributed to its diverse array of bioactive compounds. Flavonoids, phenolic acids, tannins, and essential vitamins present in the fruit have been shown to mitigate oxidative damage by neutralizing free radicals and modulating the activity of inflammatory mediators, such as cytokines and enzymes. Notably, phenolic compounds in date palm fruit exhibit strong free radical-scavenging activity, which helps reduce cellular oxidative stress an important factor in the development of chronic inflammation [5]. Furthermore, flavonoids have demonstrated the ability to inhibit pro-inflammatory signaling pathways, such as NF-κB and COX-2, which are key regulators of the body's inflammatory response. The synergistic interactions of these compounds position date palm fruit extract as a promising candidate for the development of novel anti-inflammatory therapies [6]. However, despite the promising bioactive properties of date palm fruit extract, several challenges hinder its clinical application. One of the key obstacles is the bioavailability of these compounds. Many plant-derived antioxidants and anti-inflammatory agents exhibit poor bioavailability due to their limited solubility, instability within the gastrointestinal tract, and rapid metabolism. As a result, their effectiveness *in vivo* often falls short of their demonstrated potential in laboratory settings. To overcome these limitations, advanced delivery systems such as nano encapsulation and other novel formulation strategies—are being explored to enhance the bioavailability and stability of these compounds, thereby improving their therapeutic efficacy [7]. Developing effective delivery methods for date palm extract could significantly enhance its absorption and maximize its anti-inflammatory effects [8]. This study aims to investigate the untapped therapeutic potential of date palm fruit extract as a natural agent for the management of chronic inflammatory diseases. Chronic inflammation is a critical factor in the progression of numerous debilitating diseases, yet conventional treatment options are often accompanied by



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considerable limitations in terms of both efficacy and safety. Through comprehensive *in vitro* studies, this research will evaluate the anti-inflammatory and antioxidant properties of date palm fruit extract, specifically focusing on its effects on inflammatory markers and oxidative stress pathways. By elucidating the molecular mechanisms underlying the beneficial effects of date palm extract, this work aspires to position it as a viable alternative or adjunct to traditional anti-inflammatory therapies [9]. Furthermore, recognizing the challenges associated with the bioavailability and stability of plant-derived compounds, this study will explore the development of advanced delivery systems such as nano encapsulation and other cutting-edge formulations to enhance the therapeutic efficacy of date palm extract. Ultimately, the goal of this research is not only to uncover the clinical potential of date palm fruit extract but also to contribute to the growing field of natural product-based therapies by improving the accessibility and effectiveness of plant-derived bioactive compounds in the treatment of chronic inflammation.

MATERIALS AND METHODOLOGY

Materials

The following chemicals and reagents were used in the study: Ascorbic acid, Diclofenac sodium, Phenazine methosulfate (PMS), Nicotinamide adenine dinucleotide (NADH), Griess reagent, Sodium nitroprusside, EDTA, and Nitro blue tetrazolium (NBT) were all obtained from Sigma-Aldrich (Bangalore, India). Ferric chloride (FeCl_3) was sourced from Vijaya Lakshmi (Kadapa, India), while Hydrogen peroxide (H_2O_2) was purchased from HiMedia (Mumbai, India). Phosphate-buffered saline (PBS) was acquired from Titan Biotech (Bhiwadi, India).

Plant Material

Date palm fruit (*Phoenix dactylifera*) was procured from the local market and authenticated by the Pharmacognosist of Annamacharya College of Pharmacy, Rajampet, India.

Preparation of Extract

500 g of date palm fruit was ground using water to prepare a date palm fruit juice for pharmacological activity [10].

Phytochemical Investigation[11-14]

Test for Reduced Sugars

- **Molisch's Test:** Add 2 ml of the extract to alcoholic naphthol followed by a small amount of concentrated sulfuric acid (H_2SO_4). The presence of carbohydrates is indicated by a purple ring at the interface.
- **Fehling's Test:** To a small amount of Fehling's A and B solutions, add the test compound and heat strongly. The formation of a brick-red precipitate indicates the presence of carbohydrates.
- **Barfoed's Test:** Add a small amount of Barfoed's reagent to the test compound and heat in a water bath. The appearance of a green color indicates the presence of monosaccharides.

Test for Alkaloids

- **Dragendroff's Test:** Add Dragendroff's reagent to the test solution. The presence of alkaloids is confirmed by the formation of a red-colored precipitate.
- **Mayer's Test:** Add 1 ml of Mayer's reagent to 1 ml of the test solution. A color precipitate confirms the presence of alkaloids.
- **Hager's Test:** Add a small quantity of Hager's solution to the test compound. The presence of alkaloids is confirmed by the formation of a yellow-colored precipitate.
- **Tannic Acid Test:** Add tannic acid to the test solution. The formation of a buff-colored precipitate confirms the presence of alkaloids.

Test for Proteins and Amino Acids

- **Biuret Test:** Add Biuret reagent to the test solution and heat in a water bath. The presence of proteins is confirmed by the formation of a violet color.





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- **Millon's Test:** Add Millon's reagent to the test solution and heat in a water bath. The presence of proteins is confirmed by the formation of a violet color.

Test for Flavonoids

- **Alkaline Reagent Test:** Add 2-3 drops of sodium hydroxide solution to the test solution. A yellow color that turns colorless upon the addition of dilute acid indicates the presence of flavonoids.
- **Schinoda's Test:** To 2 ml of the test solution, add magnesium turnings and dropwise concentrated hydrochloric acid (HCl). A pink or red color confirms the presence of flavonoids.
- **Zinc Hydrochloride Test:** Add a mixture of zinc sand and concentrated HCl to the test solution. The appearance of a red color confirms the presence of flavonoids.

Test for Tannins and Phenolic Compounds

- **FeCl₃ Test:** Add FeCl₃ solution to the extract. The formation of a blue color indicates the presence of hydrolyzable tannins, while a green color indicates the presence of condensed tannins.
- **Acetic Acid Test:** Treat the extract with an acetic acid solution. The appearance of a red color confirms the presence of tannins.
- **Dilute Nitric Acid Test:** Treat the extract with dilute nitric acid solution. The formation of a red to yellow color confirms the presence of tannins.

In vitro Antioxidant Activity

Determination of Superoxide Anion Radical Scavenging Activity

Principle: Superoxide anions are measured by the reduction of Nitro Blue Tetrazolium (NBT) in the xanthine-xanthine oxidase system, which is inhibited by superoxide dismutase (SOD) [15].

Procedure

- Prepare 1 ml of different concentrations of the sample solution and ascorbic acid in distilled water.
- Add 1 ml of 60 μM phenazine methosulphate (PMS) in phosphate buffer (pH 7.4) and 1 ml of 450 μM NADH in phosphate buffer.
- Incubate at 25°C for 5 minutes.
- Measure absorbance at 560 nm against a blank.

Calculation

$$\text{Percentage of radical scavenging activity} = \left(\frac{\text{control OD} - \text{Sample OD}}{\text{Control OD}} \right) \times 100$$

Free Radical Scavenging Activity (DPPH Assay)

Methodology

- Prepare different concentrations (10 μg, 50 μg, and 100 μg) of the sample in Dimethyl Sulfoxide (DMSO) in test tubes.
- Add 5 ml of 0.1 mM methanolic DPPH solution to each tube and mix well.
- Allow the tubes to stand at room temperature for 20 minutes [16].
- Measure the absorbance at 517 nm. Butylated HydroxyToluene (BHT) is used as a standard.

Calculation

$$\text{Percentage of radical scavenging activity} = \left(\frac{\text{control OD} - \text{Sample OD}}{\text{Control OD}} \right) \times 100$$





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Hydroxyl Radical Scavenging Activity

Principle

Hydroxyl radical scavenging is measured by competition between deoxyribose and the test compounds for hydroxyl radicals generated from the Fe^{3+} /ascorbate/EDTA/ H_2O_2 system [17].

Methodology

- Prepare different concentrations (10 µg, 50 µg, 100 µg, 250 µg, 500 µg) of the sample in DMSO.
- Add 1 ml of Fe-EDTA solution, 0.5 ml of EDTA, and 1 ml of DMSO.
- Initiate the reaction by adding 0.5 ml of 0.22% ascorbic acid and incubate at room temperature for 15 minutes.
- Terminate the reaction by adding 1 ml of ice-cold TCA (17.5% w/v).
- Add 3 ml of Nash reagent and incubate at room temperature for 15 minutes for color development.
- Measure absorbance at 412 nm.

Calculation

$$\text{Percentage of hydroxyl radical scavenging activity} = \left(\frac{\text{control OD} - \text{Sample OD}}{\text{Control OD}} \right) \times 100$$

Nitric Oxide (NO) Radical Scavenging Activity

Principle

Aqueous sodium nitroprusside at physiological pH produces NO, which reacts with oxygen to form nitrite ions. These are measured using the Griess reagent [18].

Procedure

- Incubate sodium nitroprusside (10 mM) with different concentrations of the sample and ascorbic acid in PBS at room temperature for 150 minutes.
- Add 0.5 ml of Griess reagent and measure absorbance at 546 nm.

Calculation

$$\text{Percentage of nitric oxide scavenging activity} = \left(\frac{\text{control OD} - \text{Sample OD}}{\text{Control OD}} \right) \times 100$$

In vitro Anti-inflammatory Activity

Denaturation of Albumin

Procedure

- Prepare different concentrations of the test extract.
- Mix 1 ml of sample with 1 ml of 1% aqueous solution of bovine albumin and adjust pH to 6.8 using glacial acetic acid.
- Incubate at 72°C for 5 minutes and cool for 10 minutes.
- Measure absorbance at 660 nm [19].

Calculation

$$\text{Percentage inhibition} = \left(\frac{\text{Abs Control} - \text{Abssample}}{\text{AbControl}} \right) \times 100$$

Membrane Stabilization

Procedure

- Collect 5 ml of human blood and add 5 ml of phosphate-buffered saline (PBS).
- Incubate with different concentrations of the extract.
- Induce lysis by adding heat and measuring the absorbance at 560 nm [20].





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Calculation

$$\text{Percentage of membrane stabilization} = \left(\frac{\text{control OD} - \text{Sample OD}}{\text{Control OD}} \right) \times 100$$

RESULTS**Extraction Yield**

Approximately 500 g of crude date palm fruit was extracted using water for 72 hours. The yield of the extract was found to be 15 g.

Phytochemical Evaluation

The phytochemical analysis of Date Palm Fruit Extract (DPFE) showed the presence or absence of several bioactive compounds. The results are summarized in Table 1.

Key Findings

- Alkaloids, carbohydrates, flavonoids, and tannins/phenolic compounds were present, indicating the extract's potential antioxidant and anti-inflammatory properties.
- Proteins/amino acids and steroids were absent in the extract, suggesting that the bioactivity can be attributed to the identified compounds.

In Vitro Antioxidant Activity

1. **Reducing Power:** The reducing power of the DPFE was evaluated by measuring absorbance at different concentrations and comparing it to ascorbic acid (AA). The results showed that DPFE exhibited a strong reducing power that increased with concentration, demonstrating its potential as an electron donor for antioxidant activity as shown in Table 2 and Figure 1.
2. **Superoxide Anion Scavenging Activity:** Superoxide anion scavenging activity was measured at various concentrations of DPFE as shown in Table 3. The extract showed a dose-dependent increase in activity, with an IC₅₀ value of 9 µg/ml, indicating its effective neutralization of superoxide anions as shown in Figure 2.
3. **Hydroxy Radical Scavenging Activity:** The DPFE showed an increase in hydroxy radical scavenging activity with concentration as in Table 4. At 500 µg/ml, the extract demonstrated 79.62% scavenging activity, with an IC₅₀ value of 17.85 µg/ml as shown in Figure 3.
4. **Nitric Oxide Scavenging Activity** DPFE exhibited 101.01% nitric oxide scavenging activity at 500 µg/ml, surpassing ascorbic acid at the same concentration. The IC₅₀ value for DPFE was 10.20 µg/ml, indicating strong scavenging potential as shown in Table 5 and Figure 4.

In Vitro Anti-inflammatory Activity

1. **Protein Denaturation Inhibition:** DPFE showed 70.30% inhibition of albumin denaturation at 500 µg/ml, whereas diclofenac exhibited 85.86% inhibition at the same concentration. The IC₅₀ of DPFE was calculated to be 35.71 µg/ml, suggesting it has moderate anti-inflammatory effects as depicted in Table 6 and Figure 5.
2. **Membrane Stabilization** The membrane stabilization effect of DPFE was measured using the HRBC membrane stabilization assay, and it showed a significant percentage protection (79.52%) at 500 µg/ml. The IC₅₀ value for DPFE was 12.5 µg/ml, indicating that it can effectively stabilize cell membranes in inflammatory conditions as in Table 7 and Figure 6.

DISCUSSION

The results obtained from the in vitro antioxidant and anti-inflammatory assays suggest that Date Palm Fruit Extract (DPFE) holds significant potential as a natural therapeutic agent due to its ability to neutralize free radicals and inhibit inflammation-related processes. This discussion will focus on interpreting these findings and comparing them with existing literature.



**Antioxidant Activity of Date Palm Fruit Extract**

The antioxidant potential of DPFE was assessed through four commonly used assays: reducing power, superoxide anion scavenging, hydroxy radical scavenging, and nitric oxide scavenging. The results from these assays consistently demonstrate that DPFE has potent antioxidant activity.

Reducing Power Assay

The increasing absorbance values with rising concentrations of DPFE indicate its capacity to act as an electron donor and reduce free radicals. This ability is indicative of the presence of phenolic compounds and flavonoids, which are known for their antioxidant activity. The observed reducing power of DPFE is consistent with findings from other studies on date palm fruit and similar natural extracts, where the presence of phenolic compounds has been associated with strong reducing abilities.

Superoxide Anion Scavenging Activity

DPFE exhibited a dose-dependent increase in superoxide scavenging activity, with an IC₅₀ value of 9 µg/ml. This result aligns with studies showing that date palm fruit contains antioxidants capable of scavenging superoxide radicals, which are often implicated in the pathogenesis of various diseases. The IC₅₀ value indicates that DPFE has effective radical scavenging properties, even at low concentrations, and outperforms many common antioxidant agents.

Hydroxy Radical Scavenging Activity

Hydroxy radicals are highly reactive and can damage cellular structures, contributing to inflammation and chronic diseases. The significant scavenging activity observed in DPFE at 500 µg/ml (79.62% inhibition) demonstrates its potential to counteract oxidative damage. The IC₅₀ value of 17.85 µg/ml suggests that DPFE could serve as an effective antioxidant in biological systems, potentially reducing the risk of oxidative stress-induced diseases.

Nitric Oxide Scavenging Activity

Nitric oxide (NO) plays a dual role in the body: it is essential for normal cellular function, but excessive production of NO is associated with inflammatory responses and diseases such as arthritis and cancer. The remarkable scavenging activity observed in DPFE, with 101.01% inhibition at 500 µg/ml, indicates its strong potential to neutralize NO, which is critical for reducing inflammation. The IC₅₀ value of 10.20 µg/ml further supports DPFE's effectiveness as an anti-inflammatory agent due to its capacity to inhibit NO production.

Anti-inflammatory Activity of Date Palm Fruit Extract

The anti-inflammatory effects of DPFE were evaluated using two standard assays: protein denaturation inhibition and membrane stabilization.

Protein Denaturation Inhibition

The inhibition of albumin denaturation is a well-known indicator of anti-inflammatory activity. The observed 70.30% inhibition at 500 µg/ml of DPFE suggests its potential to prevent protein denaturation associated with inflammatory conditions. This finding aligns with previous research, where plant extracts exhibiting phenolic and flavonoid content were found to inhibit protein denaturation. While the inhibition observed in DPFE is lower than that of diclofenac (85.86%), the extract's activity is still considerable and indicates its potential as an alternative anti-inflammatory agent.

Membrane Stabilization

The stabilization of human red blood cell (HRBC) membranes is a key indicator of anti-inflammatory potential, as it reflects the extract's ability to prevent damage to cell membranes under inflammatory conditions. DPFE exhibited 79.52% protection at 500 µg/ml, which is comparable to the effects of diclofenac, a commonly used anti-inflammatory drug. This result is significant because it suggests that DPFE may offer protective effects against inflammation-induced membrane damage, which is a common feature in many inflammatory diseases.



**Maresh Yadav et al.,****Comparison with Existing Literature**

The antioxidant and anti-inflammatory effects observed in this study are consistent with previous research on date palm fruit and other related plant extracts. Studies have shown that date palm extracts, particularly those derived from the fruit, are rich in bioactive compounds, including flavonoids, phenolic acids, and terpenoids, which are known for their potent antioxidant and anti-inflammatory properties (Alhassan et al., 2016; Kassem et al., 2020). The results of this study further support the hypothesis that date palm fruit has therapeutic potential for managing diseases associated with oxidative stress and inflammation. For instance, studies by Alhassan et al. (2016) reported that date palm fruit extracts exhibited strong scavenging activity against superoxide and hydroxyl radicals, similar to the findings in this study. Similarly, Kassem et al. (2020) found that date palm fruit extracts could inhibit protein denaturation and stabilize cell membranes, in line with our results.

Mechanisms of Action

The antioxidant and anti-inflammatory activities of DPFE can be attributed to its bioactive compounds. Specifically, the presence of flavonoids and phenolic acids is known to contribute to both radical scavenging and anti-inflammatory properties. These compounds can neutralize free radicals, inhibit the activation of pro-inflammatory enzymes, and stabilize cellular membranes. Additionally, tannins present in DPFE may play a role in inhibiting protein denaturation and membrane destabilization, which are key events in the inflammatory cascade.

Potential Applications

The potent antioxidant and anti-inflammatory activities of DPFE make it a promising candidate for the development of natural therapeutic agents for conditions such as arthritis, asthma, cardiovascular diseases, and diabetes, all of which are linked to oxidative stress and inflammation. Furthermore, the ability of DPFE to scavenge free radicals and prevent protein denaturation positions it as a potential adjuvant therapy in managing chronic inflammatory diseases. Moreover, the non-toxicity of plant-based extracts, as indicated in previous studies, makes DPFE an attractive alternative to synthetic drugs, which often have side effects. Future studies could focus on the formulation of DPFE in various delivery systems to enhance its bioavailability and effectiveness in vivo.

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Table 1: Phytochemical Tests of Date Palm Fruit Extract (DPFE)

Sl. No	Test	DPFE Result
1	Alkaloids	+ve
2	Carbohydrates	+ve
3	Proteins and Amino Acids	-ve
4	Flavonoids	+ve
5	Tannins/Phenolic Compounds	+ve
6	Steroids	-ve





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Table 2: Reducing Power Activity of DPFE

Concentration (µg/ml)	DPFE Absorbance	Ascorbic Acid Absorbance
10	0.6950	0.6079
50	1.6296	1.5771
100	2.1986	1.6823
250	2.6789	2.5216
500	2.8559	2.7202

Table 3: Effect of DPFE on Superoxide Anion Scavenging Activity

Concentration (µg/ml)	DPFE % Activity (±SEM)	Ascorbic Acid % Activity (±SEM)
10	55.45±6.60	40.82±3.94
50	59.14±5.14	47.78±5.58
100	70.82±4.80	65.70±6.57
250	76.41±8.46	76.51±5.57
500	86.00±4.73	92.34±3.41
IC50	9	12.2

Table 4: Hydroxy Radical Scavenging Activity of DPFE

Concentration (µg/ml)	DPFE % Activity (±SEM)	Ascorbic Acid % Activity (±SEM)
10	28.00±3.6	12.14±0.44
50	32.00±2.9	42.00±3.9
100	49.81±4.8	58.00±6.2
250	55.28±6.2	78.00±1.4
500	79.62±2.1	99.00±2.1
IC50	17.85	11.90

Table 5: Nitric Oxide Scavenging Activity of DPFE

Concentration (µg/ml)	DPFE % Activity (±SEM)	Ascorbic Acid % Activity (±SEM)
10	48.61±4.62	27.69±5.66
50	63.15±4.07	56.15±13.49
100	84.61±9.5	71.53±13.72
250	92.46±14.46	98.30±14.95
500	101.01±3.19	135.61±23.95
IC50	10.20	17.85

Table 6: Albumin Denaturation Effect of DPFE

Concentration (µg/ml)	DPFE % Activity (±SEM)	Diclofenac % Activity (±SEM)
10	13.53±7.35	0
50	24.35±26.73	0
100	29.69±6.2	0
250	47.74±6.0	0
500	70.30±8.08	85.86±3.82
IC50	35.71	26.31

Table 7: Membrane Stabilization of DPFE

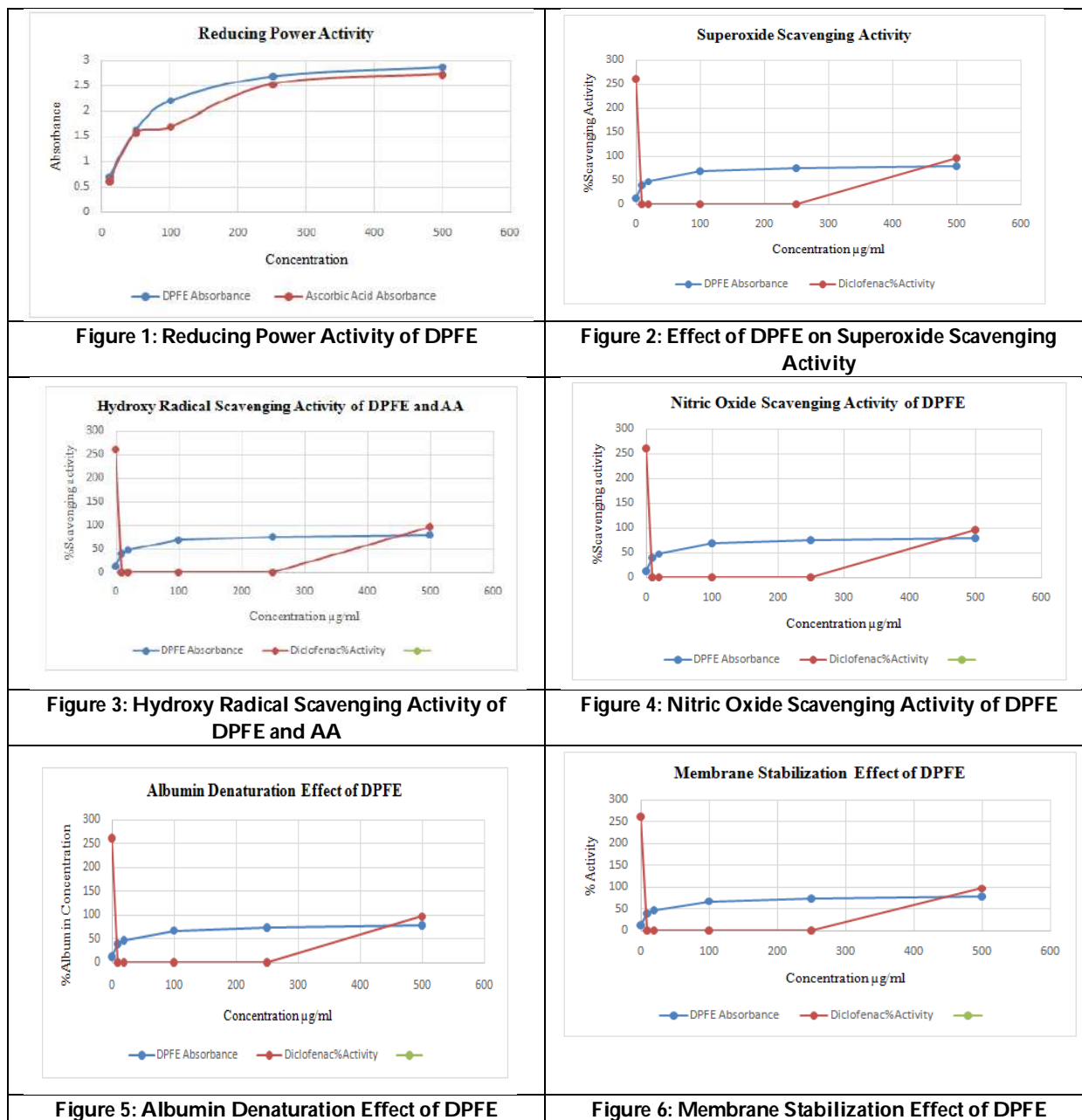
Concentration (µg/ml)	DPFE % Activity (±SEM)	Diclofenac % Activity (±SEM)
10	39.47±3.28	0
20	47.25±5.58	0
100	68.14±16.39	0





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250	74.54±3.32	0
500	79.52±2.44	96.2±2.45
IC50	12.5	260.41





Influence of *Cereus repandus* Stem Extract on the Corrosion Inhibition of Mild Steel in 1N HCl Solution and Quantum Chemical Approach

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ABSTRACT

Extract of *Cereus repandus* (CeR) was investigated as corrosion inhibitor of mild steel in 1 N Hydrochloric acid medium using phytochemical screening, weight loss method, surface examination analysis and quantum chemical studies. Stability of inhibition efficiency of CeR extracts was examined by weight loss method and maximum inhibition efficiency of CeR extract was 95 % in 1 N HCl for immersion period of 5 h at 2.5 % v/v. Scanning electron microscopic analysis established formation of protective layer on mild steel surface. Quantum studies showed molecular orbital nucleophilic and electrophilic regions present in phytoconstituents of CeR extract. Scanning electron microscopic studies revealed evidence of improved surface condition, due to adsorption of phyto constituents for the corrosion protection.

Keywords: *Cereus repandus* (CeR), Mild Steel, Phytochemical, Inhibition Efficiency, Corrosion Rate.

INTRODUCTION

In industrial environments steel are affected from completely different corrosion attacks as a result of acids like vitriol and acid throughout numerous industrial processes acid pickling, chemical cleanup and acidification [1]. Naturally occurring molecules exhibit a strong affinity for metal surfaces and facilitate toward the event of environmentally friendly corrosion inhibitors. Presently numerous plant extracts containing mixture of compounds





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oxygen, sulphur and nitrogen elements are used as inexperienced corrosion inhibitors from acidic resolution. Generally plant extracts are non hazardous friendly, cheap, readily out there and renewable sources [2].

Aim of the present work was to investigate *Cereus repandus* stem extract (*CeR*) in order to find a naturally occurring, cheap and environmentally safe substance that could be used for inhibition purposes.

MATERIALS AND METHODS

Collection of *Cereus repandus* Plant Extract Preparation

Cereus repandus stem (Figure 1) collected from Karumathampatti, Coimbatore District, Tamil Nadu, India, were cleaned and shade dried. The dried stem were powdered and stored in dessicator to prevent moisture contents. 25 gm of dried stem powder were boiled in 500 mL of 1N HCl in reflux condenser for 3 h and was kept overnight. The following day the extract was filtered and filtrate volume was made up to 500 mL using respective acid. Extract was taken as 5 % stock solution and from this other concentrations were prepared (Figure 2).

Phytochemical Analysis

Standard procedures were employed to the test the presence of alkaloids, carbohydrates, flavonoids, phenols, saponins, tannins, terpenoides, quinines and proteins in stem powder of *Cereus repandus* [3, 4].

Preparation of Mild Steel Coupons

Mild steel specimens of size 5 x 1 x 0.2 cm were cut from a large sheet of mild steel obtained from local steel house, Coimbatore, India. A small hole of about 1.0 mm diameter near 1.5 cm side end for suspending. Specimens were decreased with acetone pickled in conc. HCl and washed with distilled water and specimens were polished with 400 and 600 grade emery papers, cleaned, dried, stored in dessicator to avoid the adsorption of moisture [5].

Material Preparation

Pre weighed mild steel specimens were suspended with the help of glass hook in 100 mL of 1N HCl acid solution in the absence and presence of inhibitor at various concentrations under an immersion time period at room temperature. The specimens were removed after specified time interval, washed with distilled water, dried and reweighed. Experiments were performed for various concentrations such as,

- Concentration variations : (0.10 % v/v, 0.50 % v/v, 1.00 % v/v, 1.50 % v/v, 2.00 % v/v and 2.50 % v/v).
- Different time interval : (1 h, 3 h, 5 h, 7 h and 24 h).

The rate of the dissolution of the metal was calculated in the term of Corrosion Rate (CR) using the expression [6, 7],

$$\text{Corrosion Rate (CR)} = \frac{87.6 \times W}{DAT} \text{ (mm/y)} \quad (1)$$

Where, mm/y - millimeter per year, W - loss in weight in milligrams, D - metal density in g/cm³ (7.86g/ cm³), A - area of the sample in square centimeters, T - time of exposure of the metal surface in hours.

The percentage inhibition efficiency (IE %) of the inhibitors in terms of concentration has been calculated from the expression [8],

$$\text{Inhibition Efficiency (IE \%)} = \frac{\text{Weight loss without inhibitor} - \text{Weight loss with inhibitor}}{\text{Weight loss without inhibitor}} \times 100 \quad (2)$$

Where W₀ and W_i are the weight loss values in absence and in presence of the inhibitor respectively.

Surface Morphology

Surface analysis studies of mild steel specimens were done in order to study that occurrence during corrosion of mild steel in absence and presence of inhibitor in acid medium. Nature of metal surface was analyzed by Scanning Electron Microscope (SEM) and Fourier Transform Infrared Spectroscopic (FTIR) Studies.

Computational Chemistry

Theoretical quantum chemistry mainly involves computational chemistry which helps us to calculate predictions of quantum theory atoms and molecules can only have discrete energies [9]. Molecular properties related to reactivity and selectivity of inhibitors like ionization potential (I) and electron affinity electro negativity (χ), global hardness (η)



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and softness (σ) were estimated according to Koopmans's theorem [10]. MOPAC is a popular computer program used in computational chemistry.

RESULTS AND DISCUSSION

Phytochemical Analysis

Phytochemical analysis of *Cereus repandus* stem extract showed the presence of Proteins, Tannins, Carbohydrates, Phenols, Flavonoids, Saponins, Glycosides, Steroids, Terpenoids and Alkaloids.

Weight Loss Measurement

The effect of immersion on corrosion rate and inhibition efficiency was studied. The immersion time range from 1 h, 3 h, 5 h, 7 h and 24 h. The results of the weight loss measurements of mild steel for various concentrations of CeR in 1N HCl at room temperature after varied time period of immersion are given in Table 2. This evidenced by decrease in corrosion rate with addition of plant extract to acids. It was found that inhibition efficiency increased with increase in concentration from 0.10 % v/v to 2.5 % v/v and with increase in time due to adsorption of plant compound on to surface of metal and contribute protective layer (Figure 3).

Scanning Electron Microscopy (SEM)

The surface morphological characteristics of the uninhibited mild steel in 1N HCl and inhibited mild steel using CeR extract in 1 N HCl was analyzed. SEM photographs of the mild steel specimens after immersion in 1 N HCl for 3 h room temperature without and with inhibitor containing optimum concentration of (2 % v/v) plant extracts are presented in (Figure 4 and 5). Inhibitive action due to formation of protective film by the phytochemical components present in plant extract on mild steel.

Quantum Chemical Calculations

Structures of phytoconstituents of CeR stems extract were first optimized and simulations were conducted to calculate electronic parameters. The output of MOPAC program reports values such as ionization potential, Eigen values, dipole moment etc. According to Koopmans theorem ionization potential are negative of Eigen value of highest occupied molecular orbital (HOMO). Optimized structures of compounds studied are given in (Figure 6). Table.3 represents Quantum chemical parameters for organic molecules present in CeR stem extract. Energy of highest occupied molecular orbital (EHOMO) measures tendency of molecule to donate electrons. Therefore, higher values of EHOMO indicate good tendency towards contribution of electron, enhance adsorption of inhibitor on metal surface and demonstrate better inhibition efficiency [11]. ELUMO indicates ability of molecule to accept electrons [12]. Frontier molecular orbital diagrams of phytoconstituents of stem extract are represented in Figures 7 and 8. The energy of lowest unoccupied molecular orbitals indicates ability of molecule to accept electrons. The lower value of ELUMO, more probability of molecule to accept electrons. The higher energy gap (ΔE) may enhance corrosion inhibition efficiency. From the results of the quantum chemical calculations, it was evident that 2-Methoxy-4-vinylphenol which was the best inhibitor has the highest value of EHOMO -9.223 (eV) and would be better adsorbed on metal surface [13]. The energy gap (ΔE) provides information about overall reactivity of a molecule. As ΔE decreases, reactivity of molecule increases leading to increase in inhibition efficiency of molecule. Low values of ΔE gap will render good inhibition efficiencies since energy to remove an electron from last occupied orbital will be minimized.

CONCLUSIONS

Results obtained from experimental data showed that CeR stem extract act as an effective inhibitor for the corrosion of mild steel in 1N HCl. CeR extract showed the presence of Proteins, Tannins, Carbohydrates, Phenols, Flavonoids, Saponins, Glycosides, Steroids, Terpenoids and Alkaloids. Maximum inhibition efficiency was observed at an optimum concentration of 2.50 % v/v. The inhibition efficiency increased with the increasing concentration of





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inhibitor. CeR showed maximum of efficiency 95.30 % in 1N HCl at 5 h on immersion. The surface analysis by SEM confirmed the presence of protective film on mild steel surface in the presence of inhibitors. Quantum chemical parameters such as highest occupied molecular orbital (HOMO), lowest unoccupied molecular orbital (LUMO), energy levels, HOMO – LUMO energy gap and electronic density were identified. Quantum analysis demonstrated reactive centers of electrophilic and nucleophilic attack and strong inhibition properties of bioactive molecules of CeR. From experimental and theoretical analysis, CeR in 1N HCl acid can be used as corrosion inhibitor for mild steel as corrosion preventive inhibitor.

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Table 1 Phytochemical Screening of Stem Extract of *Cereus repandus*

Compounds	<i>Cereus repandus</i>
Alkaloids	+
Phenols	-
Flavonoids	-
Proteins	-
Carbohydrates	+





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Terpenoids	-
Saponins	+
Glycosides	+
Quinones	+
Coumarins	++
Phytosterols	-

"+" active compound present, "-" active compound absent

Table 2 CR of Mild Steel and IE of CeR Extract in 1N Hydrochloric Acid in Different Concentration and Different Immersion Studies

Conc. of Extract (% v/v)	1 h		3 h		5 h		7 h		24 h	
	CR mm/y	IE %	CR mm/y	IE %	CR mm/y	IE %	CR mm/y	IE %	CR mm/y	IE %
Blank	57.06	-	56.80	-	53.63	-	50.84	-	48.17	-
0.10	10.92	80.85	9.58	83.13	8.20	84.70	8.85	82.50	8.90	81.53
0.50	8.80	84.57	7.02	87.63	5.55	89.65	7.36	85.62	8.02	83.36
1.00	7.24	87.30	6.09	89.27	4.97	90.73	6.02	88.16	6.92	85.63
1.50	6.35	88.86	5.31	90.65	4.35	91.89	4.71	90.73	5.41	88.77
2.00	5.57	90.23	4.61	91.89	3.92	92.68	4.39	91.36	4.87	89.89
2.50	4.57	91.99	3.31	91.17	2.52	95.30	3.14	93.83	4.59	90.47

Table 3 Quantum Chemical Parameters for Organic Molecules of CeR Stem Extract

S.No	Compounds	E _{HOMO} eV	E _{LUMO} eV	Energy Gap (ΔE)eV
1	(3-Methyloxiran-2-yl)methanol	-9.560	1.285	10.845
2	2-Hydroxy-gamma-butyrolactone	-10.213	0.808	11.021
3	2-Methoxy-4-vinylphenol	-9.223	-0.013	9.210
4	3,7,11,15-Tetramethyl-2-hexadecen-1-O	-9.153	1.420	10.573
5	9,12-Octadecadienoic	-8.829	0.520	9.349
6	cis,cis-7,10,-Hexadecadienal	-8.731	0.614	9.345
7	Oxirane, hexadecyl	-9.327	0.244	9.571
8	Pentadecanal	-8.801	0.536	9.337
9	S-1,2-Propanediol	-11.393	4.301	15.694
10	Vitamin E	-8.670	0.654	9.324



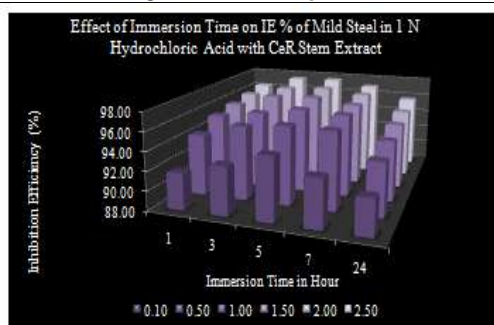
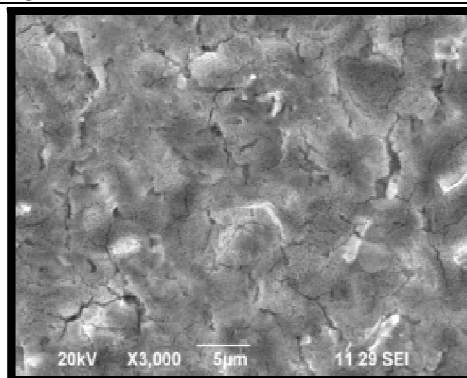
Figure 1 *Cereus repandus*Figure 2 Various Concentration of *CeR* ExtractFigure 3 Effect of Immersion Time on Inhibition Efficiency of Mild Steel in 1 N HCl Without and With *CeR* Extract

Figure 4 Mild Steel Exposed to 1N HCl Medium

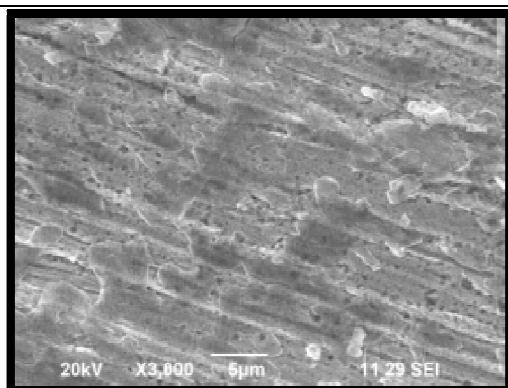
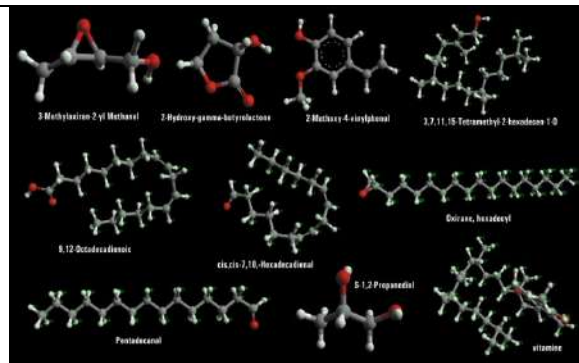
Figure 5 Mild Steel Exposed to 1N HCl + 2.5 % *CeR* Extract

Figure 6 Structure of (3-Methyloxiran-2-yl) methanol, 2-Hydroxy-gamma- butyrolactone, 2-Methoxy-4-vinylphenol, 3, 7, 11, 15-Tetramethyl-2-hexadecene-1-O and 9, 12-Octadecadienoic, cis, cis-7,10-Hexadecadienal, Oxirane, hexadecyl, Pentadecanal, S-1,2-Propanediol and Vitamin E



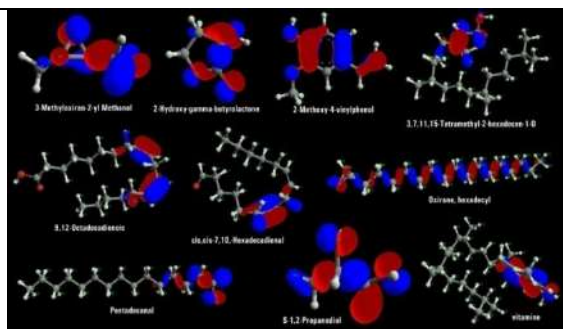


Figure 7 HOMO Orbitals of (3-Methyloxiran-2-yl) methanol, 2-Hydroxy-gamma-butyrolactone, 2-Methoxy-4-vinylphenol, 3,7,11,15-Tetramethyl-2-hexadecen-1-O and 9,12-Octadecadienoic, cis,cis-7,10,-Hexadecadienal, Oxirane, Hexadecyl, Pentadecanal, S-1,2-Propanediol and Vitamin E

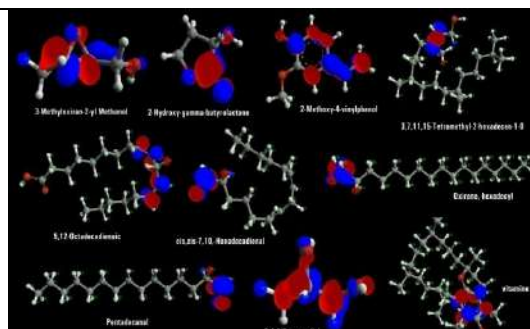


Figure 8 LUMO Orbitals of (3-Methyloxiran-2-yl) methanol, 2-Hydroxy-gamma-butyrolactone, 2-Methoxy-4-vinylphenol, 3,7,11,15-Tetramethyl-2-hexadecen-1-O and 9,12-Octadecadienoic, cis,cis-7,10,-Hexadecadienal, Oxirane, Hexadecyl, Pentadecanal, S-1,2-Propanediol and Vitamin E





Assessment of Pesticide Residues in Soil of Agricultural Fields at Nanjangud Taluk of Mysore District, Karnataka, India

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ABSTRACT

The amount of pesticide residues in agricultural soil from four locations in the study area was examined in this paper. Using the high-performance liquid chromatography technique (HPLC) quantitative analysis was carried out. The ideal parameters for the separation of two pesticides were a 70:30 acetonitrile: water eluent composition, and a flow rate of 0.4 mL/min. All of the soil samples that were examined had concentrations of the pesticides Mancozeb and Atrazine ranging from 3.87 to 7.58 µg/kg and 2.25 to 3.97 8.36 µg/kg, respectively. The outcomes were contrasted with the maximum residue limit (MRL) set by the FAO. Pesticides beyond this threshold should be closely watched as they are probably going to pose a serious risk to human health.

Keywords: Pesticide, Mancozeb, Atrazine, Chromatography.

INTRODUCTION

The soil and water degradation is a result of the growing and ongoing usage of pesticides. Pesticides have the power to eliminate or suppress organisms that pose a threat to living things these consist of herbicides, fungicides, insecticides, and so on (British Crop Protection Council, 2003). Growing agricultural production is necessary to meet the world's rising food demand, which leads to the widespread use of pesticides. Nevertheless, the extensive or prompt use of pesticide ingredients for farming causes soil pollution (Caldas et al., 2011). The physicochemical characteristics of the soil and water body, including the presence of clay minerals, organic matter, pH, climate, and other variables, affect the destiny of pesticides in these environments (Singh, 2001). Global pesticide consumption has

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risen by more than 40% in the last 20 years and has leveled out at about 4.1 million tons per year since 2017 (FAOSTAT, 2021). Pesticides and other chemicals can be maintained in soil, an essential agricultural resource. In essence, pesticide residues found in the surface or soil can enter the groundwater. There are two methods by which pesticides can enter the soil: (1) by spraying the soil during the germination stage and washing the leaves of mature plants, and (2) by releasing the granules that are administered directly to the soil (Rial Otero et al., 2003). Pesticides in soil and degradation products pose a significant environmental threat, contaminating food chains, promoting biomagnification, and causing health issues. Chronic exposure, particularly in farm workers and the village population, is a growing concern (Pathak et al, 2022). Especially when records of pesticide use are accessible. Although laboratory and controlled field studies necessary for the approval of new active ingredients (prospective risk assessments) have provided information on the short-term behavior of pesticide residues in soils following applications, there are currently insufficient observations addressing the long-term fate and in-situ occurrence of residues in soils under real-world conditions, which would enable retrospective exposure assessments (Silva et al., 2019). The usage of large volumes of solvent and a lengthy analysis time are the drawbacks of the liquid-solid extraction approach used to determine the residual pesticides in the soil; however, these issues can be resolved by other extraction techniques, such as ultrasonic solvent extraction. Its benefits include reduced solvent use, speed, and selectivity. Although ultrasonic solvent extraction improves extraction efficiency, a clean-up is necessary to get a clean extract due to its poor selectivity. High-performance liquid chromatography (HPLC) was utilized to identify and measure pesticide residues (Lesueur et al, 2008). Chromatography is a technique that uses an adsorbent column in a flow system to separate the combined components. Samples are added to the mobile phase that passes through the stationary phase in chromatographic separation. Certain thermolabile or extremely polar chemicals, as well as molecules with a large molecular weight, were analysed using HPLC. The precision with which chromatographers choose and use the column, stationary phase, and mobile phase also has a significant impact on the outcome of an analysis (Moldoveanu, S and David, V., 2013; Rouessac, F. and Rouessac, A., 2007). In this research paper, the soil sample pesticide quantity at Nanjungudtaluk of Mysuru, Karnataka district, India was analyzed using the HPLC technique.

MATERIAL AND METHODS

Chemicals

Mancozeb (Sigma-Aldrich), 99% acetonitrile (Merck), and atrazine (Sigma-Aldrich).

Study Area

Soil samples were collected from Nanjangud taluk of Mysuru district, India shown in Figure 1. Four samples were from the location and each sample was given a name as soil N1, N2, N3, and N4. The 12 to 15 cm of soil was placed in a polythene bag for study. Samples of soil were sieved, dried, and sealed in a zip-lock polythene bag.

Sample preparation

The 60 milliliters of acetonitrile were added to the 20-gram soil sample. The 100 ml beaker glass was filled with the solution. It was sonicated for two minutes after being agitated for an hour. Filter paper sized 0.2 μm was used to filter the extract (Marselina Theresia Djue Tea et al, 2018). The Mancozeb is Manganese–zinc ethylenebis(dithiocarbamate) standard was made by diluting it with acetonitrile solvent until a standard solution of 30 mgL^{-1} was obtained, and the Atrazine is 6-chloro-N-ethyl-N'-(1-methylethyl)-triazine-2,4-diamine standard was made by diluting it with acetonitrile solvent until concentration of 10 mgL^{-1} . The standardized amounts were 10 mgL^{-1} of Mancozeb and 30 mgL^{-1} of Atrazine.

High Performance Liquid Chromatography (HPLC)

Determination of the optimum wavelength was performed by the separation condition of the HPLC instrument, with eluent composition and the selected flow rate (optimum condition), with the variation of wavelength (220, 230, 240, 250, and 260 nm). The mobile phase is acetonitrile: water ratio is (80:20), (70:30), (60:40), (50:50). The qualitative



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analysis was carried out by comparing the retention time of the standard MET with the retention time of the peaks from the Myrmeleon sp. Chromatogram, which increases the peak area by injecting standard Mancozeb and Atrazine (Marselina Theresia Djue Tea et al, 2018).

RESULTS AND DISCUSSIONS**Liquid chromatography –UV**

Figure 2 and Table 1 show the four samples' ion chromatograph values as per the graph the NS-2 shows the highest concentration of Mancozeb and Atrazine when compared with the other 3 samples. The Mancozeb and Atrazine samples NS-2 show the lowest in NS-1 and NS-4 respectively. As per the standards two pesticides were above the limit in all 4 soil samples. The acetonitrile-water compositions produced by the Mancozeb and Atrazine separation chromatogram and the compound's retention period increased with the amount of acetonitrile solvent utilized, as Figure 3 demonstrates. To prolong the retention of the more non-polar chemicals in the column, polar solvents and nonpolar columns were utilized. When the mobile phase compositions were 70:30, both compounds separated satisfactorily with less than 32 minutes retention times for each component. Figure 4 demonstrated that a lower standard peak area was produced by a quicker flow rate. Therefore, it can be concluded that 0.4 mL/min was the ideal flow rate for the separation of Mancozeb and Atrazine. The 4 soil samples work nicely in a 70:30 acetonitrile-water ratio and the flow rate is 0.4 mL/min this value is similar to Marselina Theresia Djue Tea et al, 2018.

CONCLUSION

The eluent composition of acetonitrile: water ratio of 70:30 and a flow rate of 0.4 mL/min were ideal for the separation of two pesticides. When compared to atrazine, the results from this study indicate that soil has a higher persistence of pesticides, especially Mancozeb pesticides. It was gathered for this study by the FAO/WHO. Maximum levels of pesticide contamination of the soil in Nanjungud were spotted. The mancozeb pesticide samples have low concentrations found in NS-1 and high in NS-2. The Atrazine pesticides were found highest in NS-2 and low in NS-4.

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Conflict of interest

There is no conflict of interest among authors.

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Table 1. The concentration of Pesticides in soil ppm by HPLC.

Samples	Mancozeb	Atrazine
NS-1	3.87	2.78
NS-2	9.87	3.97
NS-3	4.56	2.34
NS-4	7.58	2.25

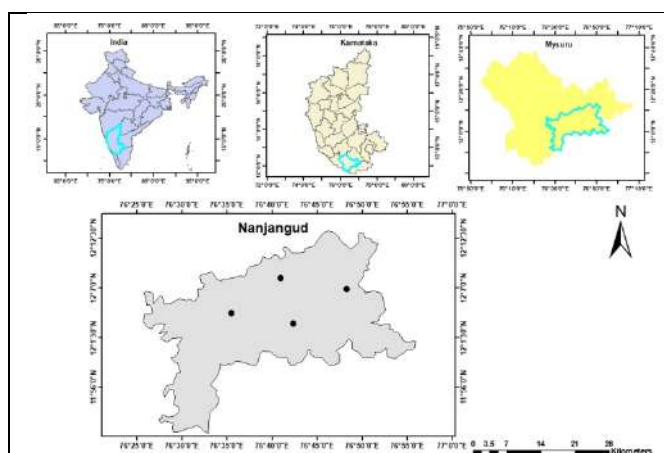


Figure 1. Location map of the study area.

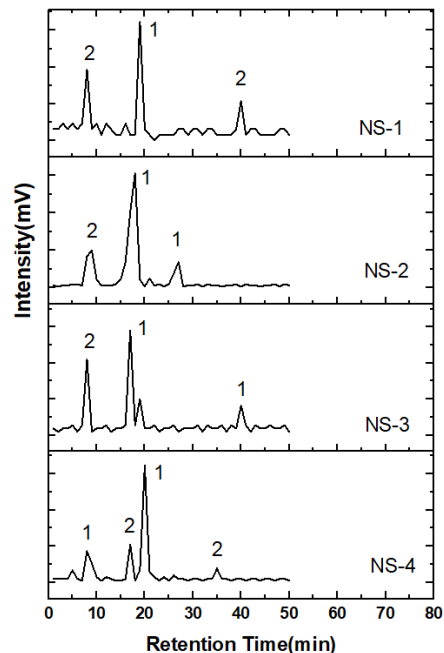
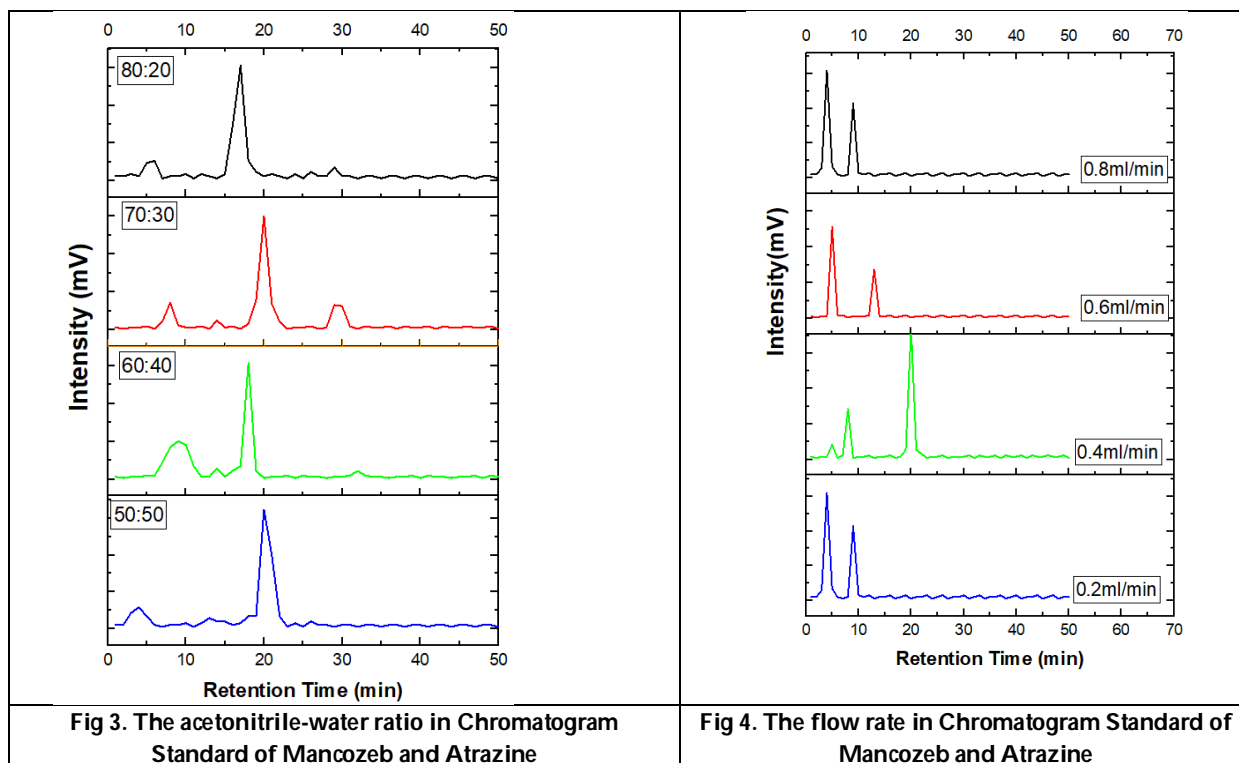


Figure 2. Ion chromatography graph 1) Mancozeb and 2) Atrazine





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Koch's Spine : A Complex Case of Extra Pulmonary Tuberculosis with Multisystem Involvement

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ABSTRACT

Koch's spine, or tuberculous spondylitis, is a severe form of extrapulmonary tuberculosis marked by severe spinal pain and possible neurological issues. Despite public health improvements, its incidence remains high in India, accounting for about 10% of all spinal tuberculosis cases. A 55-year-old man, who has a medical history of Type 2 diabetes mellitus, hypertension, and chronic kidney disease requiring ongoing hemodialysis, presented with ongoing lumbar pain, fever, and unintentional weight loss. Magnetic resonance imaging (MRI) indicated vertebral collapse at the D9 level, along with unusual signal intensities observed at the D8-D10 levels, which are indicative of Koch's spine. Additional findings included anemia, signs of systemic inflammation, and kidneys that were contracted with grade III parenchymal alterations. The comprehensive treatment plan encompassed anti-tubercular therapy (ATT), pain management, supportive care, and the application of a spinal brace. This case highlights the complex interplay between chronic comorbidities and tuberculosis, complicating the progression of Koch's spine. Timely diagnosis through imaging and clinical assessments, along with a multidisciplinary approach, is essential for managing the disease and its complications, such as neurological deficits. The treatment plan





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aimed to provide symptomatic relief while targeting the underlying infection, ultimately achieving stabilization in a challenging medical context. This situation underscores the importance of increased vigilance regarding Koch's spine in endemic areas such as India. To effectively address this condition, it is essential to implement timely diagnostic measures, customized treatment plans, and collaborative care strategies aimed at reducing the morbidity and mortality linked to this disease.

Keywords: Koch's Spine, Extrapulmonary Tuberculosis, Chronic Kidney Disease, Multidisciplinary Management, Antitubercular Therapy.

INTRODUCTION

Spinal tuberculosis (TB) represents a small fraction, specifically 1–2%, of the total TB cases and is recognized as a prevalent form of extrapulmonary TB. Within the broader category of musculoskeletal TB, which constitutes approximately ten percent of all TB instances, spinal involvement accounts for half of these cases [1]. While spinal TB is fundamentally a skeletal condition, it can also affect the nervous system secondarily, resulting in a range of neurological impairments. The occurrence of neurological complications associated with spinal TB varies significantly, with reported rates ranging from 10% to 41% [2]. The application of contemporary anti-tubercular medications, combined with appropriate rest and mobilization facilitated by suitable orthotic devices, can lead to effective biological management of the disease. This approach not only enhances the quality of life but also promotes improved functionality of the affected joint. Surgical intervention becomes necessary in cases where the diagnosis remains ambiguous, in instances of widespread lesions accompanied by abscess formation, in situations involving a potentially unstable spine with or without neurological impairment that requires stabilization, and in cases of persistent disease in adults or in children where there is a risk of progressive kyphosis as they grow [3]. The diagnosis of atypical spinal tuberculosis remains challenging, primarily due to insufficient focus on the condition and limited descriptions available in the existing literature. This lack of attention can hinder timely and accurate diagnosis, which is crucial for the appropriate initiation of treatment, especially regarding the choice of surgical interventions. Atypical manifestations of spinal tuberculosis may present as lesions localized to the sacrum or the posterior components of the neural arch, while the intervertebral disc and vertebral body remain unaffected. The phenomenon of composite lesions or pan-vertebral involvement refers to the occurrence of posterior spinal tuberculosis in conjunction with anterior spinal tuberculosis at the same anatomical level [4].

CASE DETAILS

A 55-year-old male was admitted to the hospital with vital signs, including a blood pressure reading of 195/100 mmHg, a respiratory rate of 20 breaths per minute, and an oxygen saturation level of 96% while breathing ambient air. The patient's random blood glucose level was also measured at 175 mg/dL. These observations suggest the presence of uncontrolled hypertension alongside moderately elevated blood glucose levels, necessitating prompt medical attention and vigilant monitoring throughout his hospitalization. The patient exhibited lumbar pain that had been ongoing for three months, with a notable increase in severity over the last two days, which has hindered his ability to sit following dialysis treatments. He also mentioned experiencing intermittent fever during the past five months. Additionally, the patient reported issues with constipation and gastric discomfort, alongside a significant weight reduction of 5 kg within the last month. His medical history includes a 22-year diagnosis of Type 2 Diabetes Mellitus, 12 years of Hypertension, and Chronic Kidney Disease (CKD), for which he has been receiving maintenance Hemodialysis (MHD) every week for the past four years. The patient presents with a medical history of diabetes, which is currently controlled through an insulin regimen consisting of 17 units administered in the morning and 15 units in the evening. Previously, he was prescribed antihypertensive medications that included Metoprolol at a dosage of 50 mg taken twice daily, along with Torsemide at 40 mg once daily. For gastrointestinal issues, the patient received Rabeprazole at a daily dose of 20 mg and Domperidone at 10 mg taken twice daily. Management of pain and muscle spasms involved the use of Paracetamol and Chlorzoxazone, while nutritional support was provided



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through the daily intake of Tab. Riconia. Additionally, he was using syrup Lactitol Monohydrate at a dosage of 15 mL twice daily to alleviate constipation. Notably, the patient had a Percutaneous Transluminal Coronary Angioplasty (PTCA) performed two years prior due to coronary artery disease. Following a thorough clinical assessment and imaging studies, the patient received a provisional diagnosis of Tuberculosis (TB) affecting Koch's spine, accompanied by extrapulmonary manifestations. To address the acute symptoms, the patient was administered intravenous tramadol to provide immediate pain relief, alongside a continuous infusion of fentanyl for ongoing analgesia. To manage nausea, a dose of 4 mg of intravenous Ondansetron was given. The initiation of antitubercular therapy (ATT) involved the administration of 600 mg of Ethambutol, complemented by 40 mg of Pyridoxine HCl to mitigate the risk of drug-induced neuropathy. Furthermore, supportive treatments included the use of Gabapentin in conjunction with Nortriptyline to alleviate neuropathic pain, Thiocolchicoside to address spasticity, and the application of a spinal brace to ensure stabilization and support. Laboratory assessments indicated the presence of Anemia, characterized by a diminished red blood cell (RBC) count of 3.49 million/ μ L, a hemoglobin concentration of 8.7 g/dL, and a packed cell volume (PCV) of 26.5%. These results point to a considerable degree of anemia, likely to have multiple underlying causes. Additionally, serum creatinine levels were significantly elevated at 9.5 mg/dL, suggesting severe renal dysfunction, potentially indicative of chronic kidney disease.

Furthermore, hypoproteinemia was observed, with total protein levels recorded at 5.9 g/dL and serum albumin at 3.3 g/dL, which may reflect either nutritional deficiencies or the presence of systemic inflammation. Imaging investigations yielded significant information regarding the patient's health status. An abdominal ultrasound demonstrated the presence of bilaterally contracted kidneys exhibiting grade III parenchymal alterations, indicative of chronic kidney disease. Furthermore, the ultrasound revealed grade II Prostatomegaly, mild fluid accumulation between bowel loops, and localized thickening of the bowel wall accompanied by fat stranding in the left paraumbilical area, which raised concerns for a potential inflammatory or infectious process. A subsequent CT scan corroborated the findings of small bilateral kidneys and illustrated thickening of the proximal jejunal loop wall, along with adjacent fat stranding and mild interloop fluid, thereby reinforcing the likelihood of a gastrointestinal or systemic inflammatory condition. The magnetic resonance imaging (MRI) conducted on the spinal area indicated evidence of degeneration, accompanied by an atypical signal intensity pattern within the thoracic vertebrae, especially at the D8, D9, and D10 segments. A significant observation was the collapse of the D9 vertebral body. These imaging results are consistent with the diagnosis of Koch's spine, or tuberculous spondylitis, which correlates with the clinical manifestations and initial diagnosis provided. The clinical and imaging assessments indicate a complex medical condition characterized by significant anemia, chronic kidney disease, systemic inflammation or infection, and the presence of Koch's spine with vertebral involvement. Additionally, the gastrointestinal observations may point to the possibility of concurrent extrapulmonary tuberculosis or another inflammatory disorder that necessitates further examination. These findings highlight the intricate nature of the patient's health status and emphasize the importance of a collaborative treatment strategy involving multiple specialties.

Upon admission on Day 1, the patient exhibited significant hypertension, recorded at 195/100 mmHg, alongside marked renal dysfunction. In response to these clinical findings, a regimen of antihypertensive medications was promptly initiated, which included Cilnidipine at a dosage of 10 mg administered twice daily, Metoprolol at 50 mg once daily, and Torsemide at 40 mg twice daily to manage fluid retention. Additionally, Isolazine was prescribed twice daily to provide cardiovascular support. To ensure gastroprotection, Rabeprazole was given at a dose of 40 mg once daily, while aspirin at 20 mg once daily was included for its antiplatelet effects. For glycemic management, pre-meal insulin was administered twice daily. Furthermore, dialysis was conducted to mitigate renal impairment, resulting in a reduction of blood pressure to 190/90 mmHg. On the second day, the patient indicated ongoing back pain, which was addressed through the administration of oral Tramadol daily. To target neuropathic pain, a regimen of gabapentin combined with Nortriptyline (100 mg and 10 mg, respectively, administered at night) was implemented. The initiation of dialysis resulted in enhanced urine output, signifying a favourable renal reaction to the therapeutic interventions. In cases of intense pain, intravenous Fentanyl was commenced and delivered at a rate of 200 mg in 500 mL of normal saline at a flow rate of 8 mL per hour. On the third day of observation, the patient reported persistent back pain, irregular bowel movements, and various neurological symptoms. Diagnostic imaging



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revealed the presence of extrapulmonary tuberculosis affecting the thoracic spine, commonly referred to as Koch's spine. In response, anti-tuberculosis therapy was commenced, incorporating Ethambutol at a dosage of 600 mg once daily, alongside Pyridoxine at 40 mg daily to mitigate the risk of drug-induced neuropathy. Additionally, Thiocolchicoside was prescribed at 4 mg twice daily to alleviate muscle spasms, while Prazosin was administered at 2.5 mg once daily to assist with blood pressure control. To promote bowel regularity, Lactitol Monohydrate syrup was recommended at a dosage of 15 mL before bedtime. Furthermore, a spinal brace was fitted to provide necessary stabilization. On the fourth day of treatment, the patient exhibited notable progress. Blood pressure readings fell to 150/90 mmHg, random blood glucose levels stabilized at 105 mg/dL, and urine output rose to 1500 mL per day, suggesting a recovery of renal function. The comprehensive treatment strategy employed successfully addressed the patient's systemic issues, reduced pain, and focused on the underlying tuberculosis infection.

DISCUSSION

The case of a 55-year-old man diagnosed with Koch's spine exemplifies the intricate relationships among comorbid conditions, diagnostic difficulties, and treatment approaches, both conforming to and differing from the current body of literature regarding extrapulmonary tuberculosis (EPTB). Koch's spine, which represents a type of tuberculous spondylitis, predominantly impacts the thoracolumbar area, as evidenced in this instance. This condition is particularly common in areas with significant tuberculosis prevalence, like India, where factors such as socioeconomic status, access to healthcare, and delays in diagnosis play critical roles in its ongoing prevalence[5]. This case highlights important themes in diagnosis and management that have been identified in previous research. The three-month interval between the onset of symptoms and diagnosis aligns with existing literature, which indicates that average diagnostic delays can extend up to four months, primarily due to the subtle progression of the disease and a lack of awareness. Imaging techniques, particularly MRI, play a vital role in the diagnostic process, revealing vertebral collapse and unusual signal intensities, observations that are consistent with findings in comparable cases[6, 7]. The distinctive aspects of this case are characterized by the interaction of chronic comorbidities and the implementation of a multidisciplinary treatment strategy. The commencement of antitubercular therapy (ATT), complemented by supportive measures such as gabapentin, thiocolchicoside, and the use of a spinal brace, aligns with evidence-based methodologies for alleviating neurological symptoms and maintaining spinal integrity. The significant enhancement in the patient's pain levels and systemic indicators further substantiates the efficacy of a personalized therapeutic approach. This case illustrates the essential importance of early imaging techniques in the diagnosis of Koch's spine among patients experiencing chronic back pain, particularly those with underlying risk factors such as diabetes or immune suppression. The prompt commencement of antitubercular therapy (ATT), along with supportive care measures, underscores the need for individualized treatment plans that cater to the specific requirements of each patient. Successful management of this condition necessitated a collaborative effort among nephrologists, infectious disease experts, and radiologists, thereby providing a comprehensive approach to the patient's intricate comorbidities. Additionally, this case highlights the critical need for increased vigilance regarding tuberculosis in endemic areas such as India, where delays in diagnosis can have profound implications for patient outcomes. Addressing systemic inflammation and nutritional deficiencies is crucial for enhancing recovery and improving overall patient health. Therefore, the implementation of collaborative and holistic management strategies is vital for effectively navigating the complexities associated with such clinical presentations.

CONCLUSION

The early identification of Koch's spine is crucial for effective management and ensuring a swift recovery. In patients exhibiting persistent back pain, particularly those with risk factors such as diabetes or immune suppression, it is essential to pursue advanced imaging techniques like MRI. This approach aids in the prompt detection of the condition and allows for the immediate commencement of antitubercular therapy (ATT). Timely intervention can prevent the progression of the disease, mitigate complications such as neurological deficits, and enhance overall patient outcomes. A collaborative effort among nephrologists, infectious disease experts, and radiologists is vital for





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managing comorbidities and delivering comprehensive care. In instances of severe disease characterized by significant bone involvement or the presence of abscesses, surgical intervention may become necessary. Increased clinical awareness, regular screening of at-risk populations, and effective preventive strategies, including measures to control tuberculosis transmission, are essential for alleviating the disease burden. The successful management of spinal tuberculosis underscores the significance of integrating prompt diagnosis with therapeutic interventions to achieve better prognoses and enhance the quality of life for patients.

Declaration of Patient Consent

The authors affirm that they have secured the necessary consent form from the patient, which has been properly signed. In this form, the patient has granted permission for the inclusion of their clinical information in the publication. Furthermore, the patients are aware that their names and initials will remain confidential, and appropriate measures will be taken to protect their identities.

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Author's Contribution

Dr.PS and Dr.PKY was pivotal in overseeing the case report process and offering mentorship to the students, YR, SJ, and HRSJ during the manuscript drafting phase. The clinical management and treatment of the patient were under the purview of Dr. PS, who served as the consultant physician. Under the supervision of Dr. PS and Dr. PKY, YR, and SJ actively participated in the writing and preparation of the manuscript. Ultimately, all authors engaged in a thorough review and granted their approval for the final version of the manuscript.

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A Verification Method of Human Identification using Bite Marks based on the Improved Inception V4 Model

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ABSTRACT

Bite marks analysis in forensic investigations holds paramount importance in human identification, traditional ABFO (American Board of Forensic Odontology) technique for identification of Bitemarks are time consuming, an automated recognition model for analyzing bite marks presents a significant application, offering potential advancements in machine vision-assisted identification. This study focuses on proposing a recognition method for bite marks analysis, enhancements to the Inception V4 model. This model produced the record lowest error at Image Net classification dataset. Initially, enhancements to the Inception V4 model include the addition of a dropout layer between the global average pooling layer and the Soft Max classification layer, effectively mitigating over fitting issues associated with limited bite mark datasets. Furthermore, migration learning techniques combined with the integration of the Image Net dataset during model training expedite network training while addressing challenges posed by the dataset's scale and inadequate model training. Subsequently, through experiments, the study evaluates the impact of various data preprocessing methods and dropout rates on model recognition accuracy to derive optimized model parameters. Experimental findings indicate that employing filling-based data preprocessing and a dropout rate of 0.3 yield the highest recognition accuracy, achieving up to 98.64%. Moreover, compared to classical models, the proposed enhanced Inception V4 model demonstrates a significant 18.22% increase in accuracy, accompanied by a 2.31 times faster average training time, highlighting the advantages of the proposed model. Finally, the enhanced



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Inception V4 model is integrated into a human identification system based on bite marks analysis, demonstrating the practical application value of this research endeavour.

Keywords: Image Net, Soft Max layer, Deep learning, Inception V4, ABFO technique

INTRODUCTION

Human identification with bitemark evidence is a cornerstone of criminal justice systems around the world. A significant approach for identifying criminals among the many forensic procedures available is the analysis of bite marks found on victims or at crime scenes. Bite marks, which are frequently left by violent confrontations on skin or other surfaces, create distinctive patterns. This study applies an improved Inception V4 model to a unique bite mark analysis method for person identification. In the past, forensic professionals' manual examination of bite marks has been a major component of forensic analysis. This approach is labor-intensive and prone to bias in interpretation. Through the utilisation of deep learning techniques, specifically the Inception V4 model, this study endeavours to automate the identification process and matching bite mark patterns with higher precision and accuracy. The suggested process for building the Inception V4 CNN (convolutional neural network) architecture's foundation. These improvements tackle frequent problems in the study of bitemark patterns, namely over fitting to small datasets and the requirement for reliable feature extraction from intricate bite mark patterns. Our objective is to enhance the model's performance and flexibility to various bite mark datasets by utilising state-of-the-art methods like dropout layers and transfer learning with the Inception V4 model. Furthermore, in order to appropriately evaluate the efficacy of the suggested strategy, this study emphasises the significance of rigorous testing and validation. By means of methodical assessments employing actual bite mark datasets, our objective is to exhibit the effectiveness and dependability of our methodology in contrast to current techniques. Furthermore, we investigate the augmented Inception V4 model's possible real-world forensic applications, emphasising its importance in furthering the area of bite mark analysis-based human identification. This study is a big step towards improving the accuracy and dependability of forensic bite mark analysis by using machine learning techniques. We hope to further forensic science and enable more potent techniques for person identification in legal and investigative contexts by presenting our methodology, which is built on the improved Inception V4 model.

In image processing, feature extraction is an important part and used in a wide list of computer vision problems such object recognition, classification, segmentation and pattern analysis. The main purpose of this method is to reduce the input data by highlighting important characteristics, or "features," within an image in a manner which aids algorithms in understanding and interpreting what they are analyzing. So that Feature Extraction is very important role in Image Processing. In Fig.1 diagram is a basic process for correlation between bitemarks to dental cast images using a deep learning model. It starts by inputting both types of images, followed by preprocessing them to enhance quality of output. The Inception V4 CNN model done feature extraction from both images. The extracted features are compared through a correlation step to determine their similarity. Finally, the process produces a binary output (0 or 1) to indicate whether the images match or not. To enhance performance in classification tasks can be obtained through feature extraction and help improve the accuracy of machine learning models. According to the developers, separating important characteristics including edges and contours or color distributions can make it easier to distinguish between different classes of objects. Feature extraction for querying relevant features from the data of teeth and jaws and machine learning algorithms which can set relationship between these extracted features with dental age[1]. CNN, LSTM and LSTM-CNN" — however visual elements of web pages or emails could still require image processing such as screenshots. In practice, CNNs could be applied to classify this images and infer the features that can denote a phishing attempt[2] to analyze medical imaging data (e.g., chest X-rays or CT scans) to identify patterns related to COVID-19 severity. Neural networks, particularly convolutional neural networks (CNNs), may be applied for feature extraction and classification tasks [3]. Image enhancement techniques may also be applied to improve the quality of the input images for better detection accuracy[5].In this techniques to analyze



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dental radiographs CNNs are likely used to extract features related to sexual dimorphism in dental structures. Techniques such as segmentation and classification are essential for differentiating between male and female dental characteristics[4]. Particularly OTSU's method, are used for thresholding and segmentation of electrocardiogram (ECG) signals represented as images. CNNs are then applied to classify different patterns indicative of premature ventricular contractions[7]. Image processing techniques such as edge detection and feature extraction are likely utilized to identify and compare bitemarks for human identification purposes[13] to analyze 3D scans of bitemarks in image processing techniques such as 3D modeling and surface analysis may be used to enhance the accuracy of forensic identification[19]. To detecting and identifying individual teeth in panoramic X-ray images such as point-wise localization and distance regularization are used for accurate tooth identification, combined with image segmentation to isolate teeth from surrounding structures[23]. The use of image processing for diagnostic imaging (e.g., radiographs) give broader implications of data analysis in dentistry so these techniques are transforming clinical practices[24].

Literature Survey

There are number of method in CNN architecture for image processing. Some of this CNN methods are used for image recognition and verification. Aljameel S *et al.* attempt was to develop a sophisticated model for advanced regression prediction of dental age. To do so, the authors employed deep learning frameworks that are based on four types of models: Xception, VGG16, DenseNet121, and ResNet50. It was the Xception model that showed the best prediction results with the error rate of the 6-11 period equal to 1.417. at a random height[1]. Ademir *et al.*, authors obtained dental radiographs of males and females and trained a CNN to classify the sex of a patient using the tooth image. The CNN execute with high accuracy after being testing, providing insight into the possibility of using deep learning in dentistry in the future[4]. Pallavi Tiwari *et al.*, proposed a CNN approach for brain tumor detection using diverse medical imaging data. Also created a CNN using diverse medical imaging for brain tumor detection. By normalizing the data and scaling it with data augmentation, the CNN was able to achieve high accuracy in detecting different tumor data types. This approach could also be applied to assist radiologists in their work.[5]. Alshingiti et al., to employ deep learning-based methods, including Long Short-Term Memory, as peripheral results. Those were experimentally obtained through assessing the developed system using precision, recall, accuracy, and F1 score criteria [2]. Maryam T. *et al.*, develops an algorithm using neural networks and a fitness-dependent optimizer to predict the COVID-19 severity in patients. They implemented this algorithm through a fitness-based optimizer that redefines the algorithm's parameters using the stickers' fitness. The model includes a reported high accuracy of newborn-infant patient experiences [3]. The deep convolutional neural network can also be an effective method of building-type recognition. According to the convolution layer pattern, there is a variety of patterns, such as conventional convolution, and atrous convolution, depth wise separable convolution etc. The classical convolutional network structure mainly includes Le Net [8], Alex Net [9], VGG Net [10], Res Net [11], Inception Net [12], and so on. Le Net [13] is the earliest convolutional network used for image classification tasks. It consists of 7 convolutional layers; Alex Net [9] expands the network structure to 8 layers. It is much larger in scale than LeNet[8] and introduces the ReLU activation function and image enhancement; the symmetric convolutional network, VGGNet [10] is increased to 16 layers and 19 layers, which is deeper than Alex Net but simpler in form; The symmetric convolutional network structure Res Net [11] is 8 times deeper than VGG Net[10], and Res Net[11] is simpler than VGG net like Symmetry, and has powerful feature expression capabilities, and solves the gradient disappearance problem through the residual structure. In contrast to the pattern that VGG Net[10] employs the method to vertical stack the convolution layer, Inception Net[12] uses a completely different approach: which is called building width, and improving the size of the network for global average pooling reduction and "global average pooling + full connection layer" reduction full connection layer to reduce the number of parameters at the time of computation. using three-dimensional analysis techniques involving an intraoral scanner for bite mark validation. This focuses on improving the precision of bite mark assessments through 3D imaging[19]. This pilot study compares 3D scanning techniques for bite mark analysis, emphasizing objective assessment methods over traditional techniques[20]. Utilization of Convolutional Neural Networks (CNNs) for multiclass brain tumor detection. Pallavi Tiwari *et al.* introduces a hybrid CNN model for tumor identification in medical images, integrating different machine learning approaches to improve detection performance[15]. This hybrid approach likely combines various CNN architectures or



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incorporates additional features to enhance classification accuracy[16]. R. P. Janardanan and R. Logeswaran *et al.* introduce evaluation framework for the image acquisition of human bite marks. It focuses on establishing methodologies for effective image capture and analysis rather than specific machine learning techniques[17]. The evolution of bite mark analysis and emphasizes a shift from empirical to more scientific approaches, focusing on the methodological rigor of analysis rather than a specific technical framework[18]. Along with the continuing development and application of convolutional neural networks in recent years, both classical, and classical network models have been renovated, used in many places, and can be widely used in the future.

METHODOLOGY

Dataset Description and Collection

The bite mark samples were obtained from 250 peoples. The age range was between 18-25 years. The assumption in this study for each sample was there were no missing lower and upper anterior teeth and no fixed orthodontic appliances. Each sample was asked to bite the standard pink dental wax. The bitemarks of all upper and lower anterior teeth were covered. After that, the photographs of these bite marks were taken using a digital camera. The resolution was 20.3 million pixels, and the distance between the objects and lens was maintained at 5cm. The photos were saved as JPEG files as bite mark samples and dental cast of each individuals for study.

Loading Proposed Experimental Pre-Training Framework

To improve the model's training efficiency and model recognition accuracy, as the dental cast and pink wax bitemark images dataset is small in sample size, this paper adopts a model-based transfer learning technique, transferring and applying the Inception V4 trained on the Image Net dataset to the bitemarks and dental cast verification task. During this model transfer, first the Inception V4 pre-training model has to be loaded; that is to say, train the Inception V4 model on the Image net dataset to get a pre-training model with the model's parameters. As the feature extraction methods of the data in Image Net are similar with the bitemarks and dental cast correlation but not identical, in this paper, all layers of the Inception V4 model are added to the training process to get better verification results.

Training Process of the Proposed Model

Figure 2 shows the training process of the improved CNN (Inception V4) model. The training set of Bitemark and Dental Cast images is input into the pre-trained Inception V4 model. The shallow features of the images are extracted via convolution in the first few layers of the model and pooled to reduce the feature map size, so as to further extract the deep features in the Inception block. The Inception block extracts feature maps of different sizes via parallel convolution layers. These feature maps are merged at the end of each Inception block and then input to the next layer. Then all the extracted features are input into the global average pooling layer, that is, before the results of the global average pooling layer are input to the Soft Max classification layer, adding a dropout layer, that is, randomly ignores some neuron nodes at a certain ratio, without changing the input layer and output layer. The Soft Max classification layer finally outputs the classification results and completes a forward propagation process. Once forward propagation is completed, the parameters in Inception V4 will be updated by the back propagation algorithm, the ignored neuron nodes are not updated, and the iteration is completed. Then the above steps are repeated until the end of the training process.

Process of Model Hyper parameters

In the process of model training, such key parameters as a learning rate, epoch, batch size, optimizer, loss function, evaluation metrics, etc., should be optimized and tuned. Then, such parameters are also accordingly adjusted. The learning rate is responsible for the rate of convergence of the objective function and significantly affects the learning speed. Specifically, if the learning rate is too large, then the speed of the study will also be fast, but the model's parameters may not converge if too small, then there will be slow convergence of the model. After multiple tests, the empirical learning rate is chosen to be 0.001. Batch size indicates how many images are input into the neural network at a time during training. When the memory is overloaded, the batch size is too large. When the computing resources





cannot be fully utilized, the batch size will be relatively small, and the waste will be even more. After testing, the batch size is set to 16. The Optimizer Adam is selected as the optimizer for updating the model's parameters. It can be regarded as the advantage of the fast convergence of Adam and a good feature of easy parameter tuning. In addition, the learning rate can be adjusted automatically. The formula is.

$$w_{t+1} = w_t - \frac{\alpha \cdot m_t}{\sqrt{v_t}} = w_t - \frac{\alpha \cdot (\beta \cdot m_{t-1} + (1-\beta) \cdot g_t)}{\sqrt{\beta_1 \cdot v_{t-1} + (1-\beta_2) \cdot g_t^2}}$$

Here β_1 and β_2 are two hyper-parameters of this model; β_1 controls the first-order momentum and β_2 controls the second-order momentum. The initial values of β_1 and β_2 are 0.9 and 0.999, respectively. At the same time, Adam can adaptively optimize the learning rate, taking the decay rate $\epsilon = 1 \times 10^{-7}$.

Loss function: For multi-category neural network models, the cross-entropy loss function is usually applied, and its formula is shown in Formula:

$$C = -\frac{1}{n} \sum_x [y \ln a + (1-y) \ln (1-a)]$$

Where x represents the sample, y represents the real label, represents the predicted output, and n represents the total number of samples. Metric evaluation criteria, the traditional top 1 and top 4 accuracies cannot objectively measure the model's recognition effect. Therefore, the 1st and 4th accuracy rates are used as model evaluation criteria in this paper:

- (1) 1st Accuracy: This represents the maximum value of top1 accuracy during 20 rounds of model training;
- (2) 4th Accuracy: This represents the 5th largest value of top1 accuracy during 20 rounds of model training.

EXPERIMENT AND RESULT

Fig.3 Precision graph shows that Inception V4 prediction of model is more accurate than others 4 CNN models. Above graphs shows comparison between 5 CNN models. Fig.4 shows that Inception V4 model accuracy rate is better than Alex net, VGG-16, Res net, Le Net. The 1st accuracy and the 4th accuracy on the test dataset and the average training time of the four models are shown in following Fig.5

CONCLUSION

Compared with other classical models, the recognition proposed model in this paper has the best recognition accuracy and the least model training time, which validates the effectiveness of promoting performance in the image recognition task of our proposed method using Mathematical operation. The research in this paper provides a new idea and method for the recognition of image processing's, based on Inception V4. In future research, we will further carry out the recognition of Gender identification using Bitemarks evidence. And will further improve the recognition effect by combining data enhancement, target recognition, and other methods.

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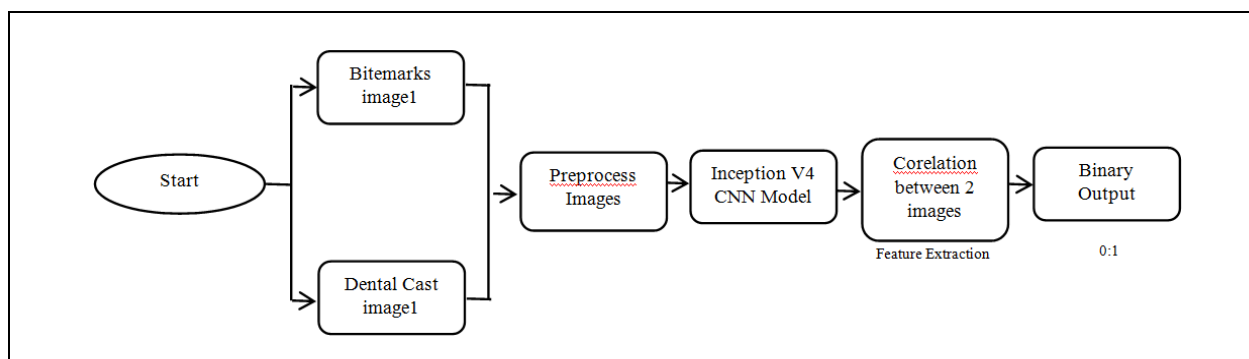


Figure.1:Block diagram of basic flow of improved Inception V4 model.

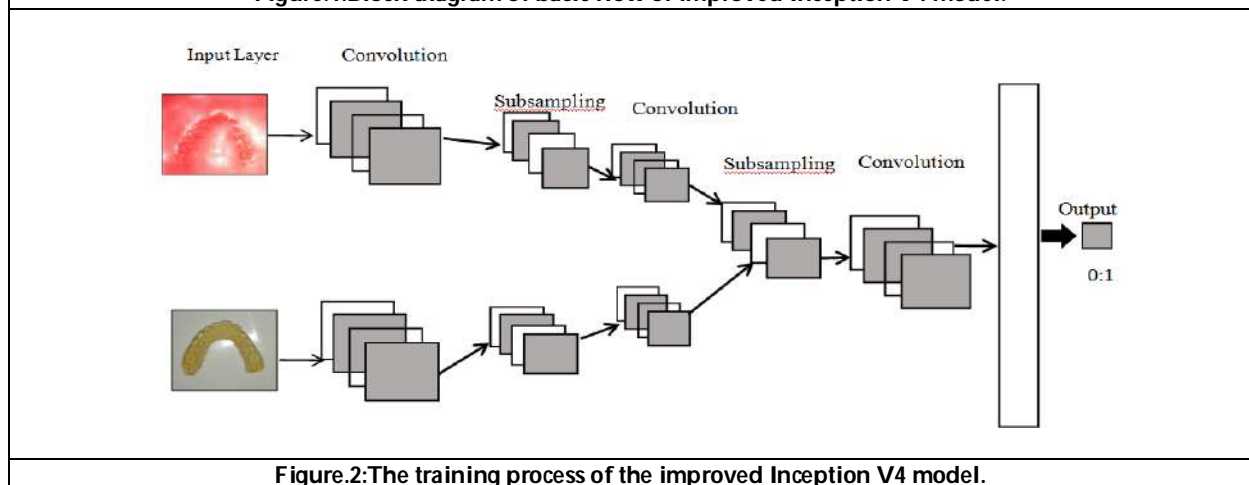


Figure.2:The training process of the improved Inception V4 model.



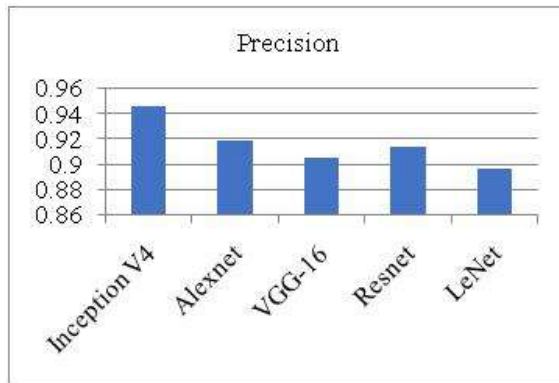


Figure.3: Precision of Inception V4 model

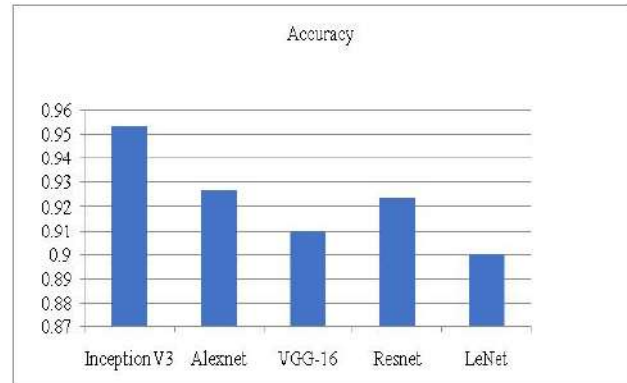


Figure.4: Accuracy of Inception V4 model

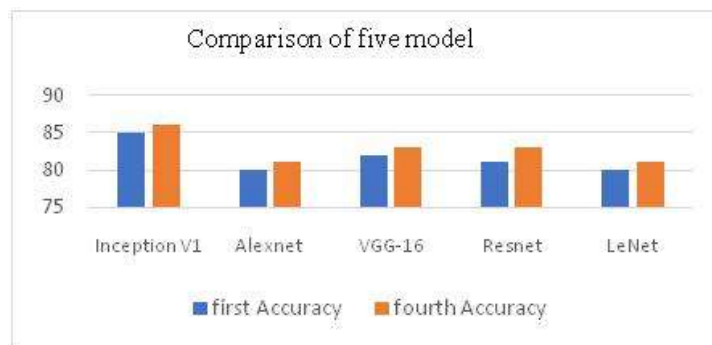


Figure.5: Comparison of five model





Advancing Liposomal Therapeutics: Breakthroughs, Barriers and Opportunities - A Review

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ABSTRACT

Liposomal drug delivery systems have emerged as a transformative technology in modern pharmaceuticals, offering innovative solutions to longstanding challenges in therapeutic delivery. These nanoscale vesicles, characterized by their ability to encapsulate both hydrophilic and hydrophobic drugs, have demonstrated remarkable potential in enhancing drug stability, bioavailability, and targeted delivery. Recent advances focus on optimizing liposome design, integrating targeting ligands, and employing stimuli-responsive release mechanisms for controlled and precise drug delivery. Notably, liposomes have expanded beyond oncology into areas such as infectious diseases, neurological disorders, gene therapy, and regenerative medicine, showcasing their versatility. The integration of nanotechnology, artificial intelligence, and precision medicine further enhances their capabilities, enabling personalized treatment strategies and real-time monitoring. Despite these advancements, challenges persist, including scalability, manufacturing complexities, regulatory harmonization, and biocompatibility concerns, requiring rigorous research and collaboration. Emerging trends, such as the development of smart liposomes and combination therapies, promise to propel the field further. Liposomal technology is poised to revolutionize disease treatment landscapes, addressing unmet medical needs while improving patient compliance and quality of life. This review explores recent developments, key challenges, and future opportunities in liposomal drug delivery systems, emphasizing their pivotal role in advancing modern healthcare and shaping the future of precision medicine.

Keywords: Liposomal Drug Delivery, Targeted Therapy, Stimuli-Responsive Liposomes, Nanotechnology Integration, Personalized Medicine



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INTRODUCTION

The 1960s discovery that hydrating dry lipids forms liposomes, miniature, membrane-enclosed vesicles resembling cellular organelles unveiled their potential as biodegradable, biocompatible vessels for drug delivery. This breakthrough hinted at enhanced therapeutic potency and reduced toxicity. Nevertheless, it took three decades for liposome technology to mature and find practical application in drug delivery systems[1]. For over five decades, liposomes have been investigated as versatile drug delivery systems. Numerous liposomal formulations have gained clinical approval for treating diverse conditions, including oncology, fungal infections, and pain management. However, inherent challenges persist in optimizing the encapsulation and controlled release of payloads, particularly for hydrophilic small molecule therapeutics. A significant obstacle is the rapid release of encapsulated drugs immediately following administration, potentially resulting in systemic or localized toxicity[2]. The past 36 years have witnessed remarkable advancements in liposome research, transforming these vesicles from bio membrane models to versatile drug delivery systems with clinical efficacy. Liposomes now play a pivotal role in various therapeutic arenas, including oncology, antifungal therapy, vaccine development, and gene therapy. Notable examples of commercially available liposomal formulations include doxorubicin, daunorubicin, amphotericin B, and vaccines against hepatitis A and influenza. This expanding landscape has fuelled interest among biopharmaceutical companies, with many now incorporating liposome-based technologies into their platforms[3]. Structurally, liposomes consist of phospholipid vesicles with one or more concentric lipid bilayers enclosing isolated aqueous spaces, enabling the encapsulation of both lipophilic and hydrophilic compounds[4]. Liposomes are characterized by a concentric lipid bilayer structure enclosing an aqueous interior. In drug delivery applications, unilamellar liposomes with diameters between 50-150 nm are commonly employed. Notably, larger liposomes undergo rapid clearance from the circulatory system. The term 'drug' is used broadly to encompass both conventional pharmacological agents, such as antifungal (Amphotericin B) and anticancer (doxorubicin) therapeutics, and genetic medicines, including oligonucleotides and plasmid DNA[5].

In the pharmaceutical domain, a multitude of commercially available medications, as well as those in various stages of development, have exploited liposomes as a sophisticated drug delivery modality. The optimization of liposomal formulations necessitates the refinement of several pivotal parameters, including augmented drug solubilization and stability in systemic circulation, attenuated clearance and volume of distribution, and prolonged circulatory half-life. Moreover, efficacious liposomal formulations should facilitate targeted drug accumulation in specific tissues (e.g., neoplastic lesions) while mitigating off-target adverse effects. The successful integration of these attributes was instrumental in the development of Caelyx™/Doxil®, the groundbreaking liposomal drug approved in the United States in 1995. [6]. Liposomes, a paradigmatic nano-scale drug delivery modality, are beset by limitations, including precipitous clearance and diminished efficacy. Polyethylene glycol (PEG) modification enhances liposomal stability and circulatory persistence. Further innovations involve conjugating affinity ligands to augment targeting specificity. Nonetheless, these modifications can introduce unforeseen consequences, underscoring the need for a facile and translatable approach to mitigate these challenges[7]. Surface modification of liposomes has proven advantageous in tailoring their mechanisms, kinetic properties, and biodistribution. Commercially available products, such as Doxil and Myocet (doxorubicin) and DaunoXome(daunorubicin), have demonstrated efficacy in treating conditions like Kaposi's sarcoma. Naturally derived phospholipids and cholesterol are used to produce liposomes, which spontaneously form bilayer spheres when combined with water[8]. Recent breakthroughs in biomedical science and combinatorial chemistry have led to the development of numerous novel therapeutic agents with promising in vitro activity against various disease targets. However, most of these potential drugs falter in clinical trials. For example, despite impressive in vitro cytotoxicity against cancer cells, many anticancer agents lack selective antitumor efficacy in vivo, limiting their clinical utility. A significant obstacle hindering antineoplastic drugs is their narrow therapeutic window, where the dose required for tumour suppression also harms healthy tissues[9]. Nanomedicines have revolutionized drug delivery, enhancing bioavailability and mitigating off-target effects. Approved nanomedicines, including liposomes and polymeric micelles, have improved cancer treatment outcomes. However, endocytosis often



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hinders efficient delivery, degrading nanomedicine cargo within endo/lysosomes. To overcome this, innovative drug delivery systems are being developed to bypass endo/lysosomal pathways, augmenting intracellular delivery and optimizing therapeutic outcomes. [10].

Opportunities and Future Trends

Liposomes have revolutionized drug delivery, offering transformative solutions in healthcare with numerous approved products. These lipid-based carriers protect drugs from degradation, regulate release for enhanced efficacy, and improve solubility and bioavailability. [43] Their ability to integrate both hydrophilic and hydrophobic compounds highlights their versatility, making them a pivotal tool in modern medicine. Liposomes boast an exceptional safety profile, allowing higher drug doses without compromising patient safety, while their extended half-life facilitates sustained-release formulations, improving patient compliance and therapeutic outcomes. [44] The development of "smart liposomes" further elevates their potential, enabling drug release in response to physiological or external stimuli such as pH shifts, temperature changes, and enzyme activity, optimizing targeted therapies. [45] The oncology landscape, in particular, has benefited from liposomal advancements. Combination therapies utilizing liposomes target multiple pathways, enhancing cancer cell destruction while reducing toxicity and side effects. [46,47] These therapies leverage synergistic effects, ensuring precise delivery of diverse therapeutic agents, including genetic payloads like siRNA and CRISPR/Cas9. This approach overcomes traditional limitations, paving the way for improved cancer outcomes. [48] Liposomes have also breached biological barriers, such as the blood-brain barrier, through surface-functionalization with ligands or antibodies. Stimuli-responsive liposomes further pioneer precision medicine by releasing drugs in response to specific bodily cues. In addition, the co-delivery of multiple anticancer agents via a single liposomal nanocarrier harmonizes drug uptake by tumor cells, enhancing combination therapy efficacy. [49] Beyond oncology, liposomes support personalized medicine, improving fertility treatments and facilitating real-time health monitoring through mobile health apps. This integration of nanotechnology and digital therapeutics enables tailored interventions, transforming healthcare delivery and empowering patients to make informed decisions. As a result, liposomes continue to redefine therapeutic possibilities, merging safety, precision, and innovation to enhance patient care. [50,51]

CONCLUSION

Liposomal drug delivery systems have advanced significantly, offering targeted and controlled therapeutic agent release to improve treatment outcomes and patient compliance. Key innovations include enhanced liposome designs for stability, biocompatibility, and versatility, as well as the incorporation of targeting ligands for precise drug delivery. Triggered release mechanisms and combination therapies further amplify their potential, enabling synergistic effects and reducing toxicity. Integration with nanotechnology has expanded liposome applications beyond oncology to infectious diseases, neurological disorders, gene therapy, and regenerative medicine. In oncology, liposomes have improved chemotherapy by enhancing drug bioavailability and minimizing side effects. Additionally, stimuli-responsive liposomes release therapeutic agents in response to pH, temperature, or enzyme activity, pioneering precision medicine. They also play a pivotal role in gene therapy, delivering genetic materials like siRNA and CRISPR/Cas9, which enable targeted gene editing. Despite these advancements, challenges remain. Scalability, manufacturing complexities, regulatory hurdles, toxicity concerns, and intellectual property issues require resolution to translate laboratory successes into clinical practice. Addressing these issues through research, industry collaboration, and standardized methods will ensure progress. Liposomes will enable tailored treatments, combat antibiotic resistance, enhance immunotherapy, and improve vaccine efficacy. With projected market growth to USD 4.4 billion by 2025, liposomes are set to transform healthcare. By reducing side effects, enhancing efficacy, and improving patient compliance, they will remain at the forefront of pharmaceutical innovation, offering new hope for diverse medical challenges.





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Table:1-Diff. type of Liposomal Classes

Liposomal Class	Categorization
Passive liposome	Anionic: Contains negatively charged phospholipids and cholesterol
Cationic liposome	Reconstituted Sendai virus envelopes are also referred to as Virosomes derived from the Sendai virus
Acid sensitive liposomes	Phospholipids like PE or DOPE are commonly paired with cholesterol or oleic acid. These combinations form lipid components for liposomes.
Lipopectin Liposome	Cationic lipids like DOTMA, DOTAP, or DDAB are often combined with DOPE.
Circulation enhanced liposome	Neutral liposomes consist of high-temperature phospholipids, cholesterol, and DSPC Contain 5%PEG

Table:2- Benefits of Liposomal Drug Delivery System

S.no	Factors	ADVANTAGE
1.	Biocompatibility	Liposomes are made up of phospholipids which make them biocompatible and non -toxic
2.	Site targeting	Liposomes are used to target specific tissues or receptor
3.	Reduced toxicity	Liposomes have lower toxic side effect than traditional drug delivery system
4.	Enhanced pharmacokinetic	Liposomes can enhance pharmacokinetic properties
5.	Improved Biodistribution	Liposomes can improve biodistribution at targeted sites

Table: 3-Targeted Application & Outcomes

Title	Targeted Application	Invitro-In vivo Studies	Limitations / Role
Endocytosis of liposome By Human T- Leukemia cells in consideration of ligand antibody	T-Leukemia cell	In-vivo study	The protein liposomes were ineffective with antibodytype antibodies against B- lymphoma.
Paclitaxel liposome based chemotherapy combined with immunotherapy combined with immunotherapy for tumour	Carcinoma and adenocarcinoma	In-vivo Study	The combination of paclitaxel liposome and immunotherapy has not been evaluated in advanced NSCLC.
Multifunctional nano particle-mediated	Lung diseases, bowel diseases, rheumatoid	In-vitro study	Interactions between therapeutic agents can





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cobining therapy for human diseases	arthritis& other cancer cardiovascular disorder		diminish their combined effectiveness, falling short of the expected additive benefit.
Multifunctional Nanoparticle-Mediated Combination Therapy for Human Diseases & Immunotherapeutic Strategies for Aging-Related Neurodegenerative Diseases: Emerging Perspectives and Novel Targets	Alzheimer including Parkinson's disease	<i>In-vivo</i> study	The therapeutic effectiveness of statins and antihypertensives in treating Alzheimer's disease (AD) and vascular contributions to cognitive impairment and dementia (VCID) remains uncertain. However, patients with overlapping pathology from both conditions may benefit from a combination of immunotherapy and cardiovascular disease management.
Inflammation ,autoimmunity and neurodegenerative therapeutics and beyond	Amyotropic lateral sclerosis (ALS),Friedreich's ataxia ,frontotemporal lateral sclerosis,alzeimer and Parkinson's disease	<i>In-vivo</i> study	Tpe with albumin exchange may slow cognitive and functional decline in AD patients.
Stimuli liposomes	Stimuli	Principle	Advantage
Photosensitive liposomes	UV, near infrared or visible light irradiation	Phospholipids modified with light-sensitive groups form the basis of photoactivable liposomes. These modified phospholipids create liposomes that respond to light. This innovation enables controlled release of liposome contents.	Controlling ,wavelength and intensity
Thermo responsive liposome liposomes	Radiofrequency or microwave ablation	Liposomes composed of lipids like DPPC, with a phase transition temperature of 40-45°C, are used for radiofrequency or microwave ablation.	Targeted drug release at high temperature sites
Reductive responsive liposomes	Reactive oxygen species (ROS),peroxides ,hydroxyl radicals singlet oxygen	Drug release is triggered by the cellular redox potential difference, which occurs naturally during biological processes. Enzymes like proteases and esterases break down	Reactive Oxygen Species (ROS) induce elevated glutathione levels in tumor cells. This increase triggers the cleavage of liposomal formulations.





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		amides or esters, releasing the loaded drugs.	The breakdown releases the encapsulated therapeutic agents, targeting the tumor cells.
Enzymatically triggered liposomes	Protease,amidaseand esterase enzymes	Enzyme-triggered release occurs through hydrolysis. Proteases and esterases break amide/ester bonds. Loaded drugs are then released.	Liposomal formulations reduce the toxicity of potent drugs, mitigating adverse side effects. They also enable the effective encapsulation of prodrugs. This targeted approach enhances therapeutic efficacy while minimizing harm.
PH-responsive liposomes	Ph change	pH-sensitive liposomes were successfully prepared using cholesteryl hemisuccinate and 1,2-dioleoyl-sn-glycero-3-phosphoethanolamine. These components enabled the creation of liposomes that respond to changes in pH levels.	Liposomes with ph activated release mechansim

Table: 4- Current Progressive Liposomal Drug Delivery

Acid groups	Description	PH Range	References
Oleic acid	pH-sensitive liposomes can release their cargo in response to acidic environments, but may be destroyed by interacting with endosomal membranes. Researchers are working to improve their stability and efficacy.	5.0-7.4	[11]
Succinic acid derivatives	A stimuli-sensitive polymer was grafted onto liposomes, creating dual-responsive liposomes that destabilize at mildly acidic pH.	4.0-5.5	[12]
Poly(Acrylic acid)	The pH-sensitive polymer network surrounding the liposomes controls the release properties. This is achieved by inserting cholesterol-terminated poly(acrylic acid) (Chol-PAA) and then crosslinking it with 2,2-(ethylenedioxy)-bis(ethylamine)	4.5-7.0	[13]
Aspartic acid	Incorporating polyaspartic acid into liposomes confers pH sensitivity, thereby augmenting tumor-targeted drug delivery and yielding enhanced cumulative release and cytotoxic efficacy.	5.0-7.4	[14]
Glutaric acid	Liposomes modified with 3-methylglutarylated hyperbranched poly(glycidol) exhibit pH-dependent behavior, dynamically shifting their hydrophilic-lipophilic balance in response to acidic environments.	5.5-7.5	[15]
Amine -protonation /deprotonation	Amine functionalities facilitate pH-dependent permeability shifts in drug delivery systems by undergoing reversible protonation and deprotonation, enabling responsive release profiles.	6.0	[16]
Phosphoethanolamine	The synergistic combination of unsaturated phosphoethanolamine species and amphiphilic stabilizers enables the creation of pH-sensitive liposomes, which undergo phase transitions in response to pH changes, triggering content release.	6.5-7.2	[17]





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Table:5-Use of Liposome in Nanoformulation

Liposomal Compound	Nano Formulation Application	Mechanism	References
Doxorubicin	Liposomal doxorubicin formulations are utilized in the management of various malignancies, including ovarian cancer, Kaposi's sarcoma, and multiple myeloma.	Doxorubicin functions by inhibiting topoisomerase 2, a crucial enzyme that cancer cells require for cell division and proliferation.	[18]
Amphotericin -B	Amphotericin B, a polyene antibiotic, pioneered the development of nanosized liposomal formulations. Liposomal encapsulation mitigates renal toxicity and amplifies the therapeutic index by associating the drug with lipids.	Amphotericin B exerts its antifungal activity by binding to ergosterol in the fungal cell membrane, leading to the formation of transmembrane pores. This results in the leakage of essential ions and ultimately, fungal cell lysis and death.	[19]
Verteporfin	Verteporfin is light -activated drug that can be encapsulated in liposomes an injectable drug that used to treat eye diseases like macular degeneration pathologic myopia and ocular histoplasmosis .Lipid based nanoparticles can be used to deliver verteporfin to PdT they are biocompatible circulate for long time .	Verteporfin is a photosensitizing agent that, upon activation by light in the presence of oxygen, produces reactive oxygen species. These reactive species selectively damage the vascular endothelium, resulting in occlusion of the targeted blood vessels.	[20]
Lidocaine	Lidocaine nanoparticle are used to enhance antitumor activity of lidocaine they are prepared by encapsulating the hydrophobic base form of lidocaine with a self - assembling peptide inhibit the proliferation of cells ,induce cell and slop down rate of lidocaine	Lidocaine mechanism id blocking voltage -gated sodium channel prevents the propagation of action potentials	[21]
Daunorubicin	Daunorubicin is is an antineoplastic drug delivered in liposomal nanomaterial to treat cancer to improve long term survival in patients .Approved to treat adults with acute myeloid leukemia and AML-with myelodysplasia.	Daunorubicin's antimitotic and cytotoxic effects arise from its ability to intercalate between DNA base pairs, forming stable complexes. This action inhibits topoisomerase II by locking the enzyme-DNA complex in place.	[22,23]

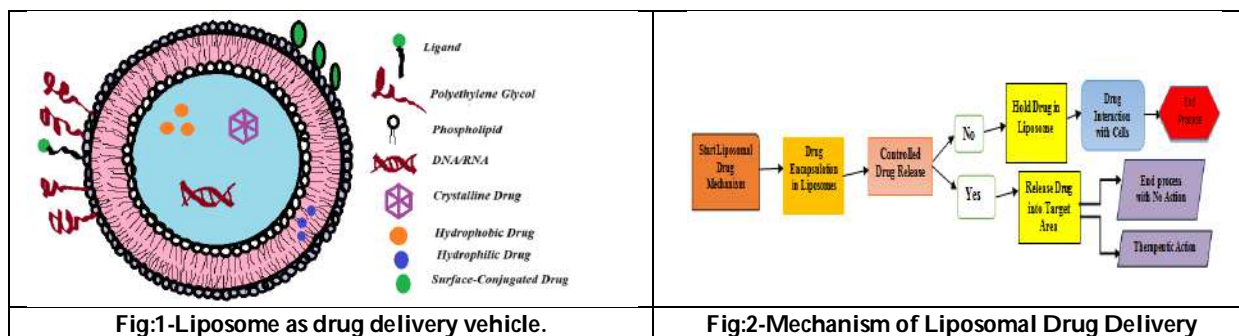
Table:6- Challenges and result of LDDS

Aspect	Advantages/Applications	Challenges/Issues	Future Directions/Insights	Reference
Liposomes in Drug Delivery	Broad compatibility with hydrophilic and hydrophobic drugs, low toxicity, enhanced drug efficacy, sustained release.	Stability, bioavailability, biocompatibility, storage challenges.	Optimize lipid composition, size, surface charge, and loading capacity.	24-25
Nanotechnology in Healthcare	Precise surgical tools, gene repair, intelligent patches for	Safety and environmental risks of	Enhance characterization, safety	26-28



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	diagnostics, 3D frameworks for tissue engineering.	nanomaterials.	protocols, and regulatory compliance.	
Lyophilization in Biologics	Improves stability and shelf-life of sensitive formulations.	Intricate process requiring optimization of formulation and parameters.	Use modeling for scale-up and reduce development time.	29-31
Reproducibility in Research	Ensures reliable results, efficient error detection, and fosters trust.	Inadequate data sharing, workflow complexity, and insufficient documentation.	Promote open science practices, standardized methodologies, and tools like Docker.	31-34
Special Populations in Research	Address health disparities, ensure tailored treatments, and promote inclusivity.	Ethical and funding challenges, underrepresentation.	Balance ethical safeguards with the need for research to improve outcomes for vulnerable groups.	35-39
Nanoparticles in Industry	Versatile applications in medicine, cosmetics, textiles, and more.	Potential toxicity, surface charge effects, and unknown health risks.	Rigorous safety assessments and regulatory frameworks to balance innovation and safety.	39-42





Behavioral Shifts in Remote Work and their Environmental Implications: A Natural Sciences Perspective

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ABSTRACT

The COVID-19 global Pandemic has brought about a total transformation of traditional work paradigms by significantly shifting the workforce at the global level towards remote work. This has inspired a novel surge in the value of flexibility alongside autonomy for individual employees. A recently conducted MIT survey found that about half of the workforce works remotely, suggesting a growing trend. While it is a fact that productivity and work-life balance is enhanced through remote work, it also presents some inherent challenges for employers as well as employees. In addition to organizational impacts, work-from-home (WFH) policies are affecting us in ways that are both ecologically and behaviourally interesting. Our commuting behaviors have been altered, leading to a temporary reduction in the key sources of urban air pollution and energy consumption. Resource use and human-environment interactions at the local levels have been altered due to continued reliance on at-home workspaces. The present study seeks to critique the WFH option and investigate the behavioral implications and intersection of remote work with natural sciences while including its environmental and ecological dimensions. The research is quantitative as it has gathered data from over 281 respondents through the survey method using a questionnaire. Secondary data sourced from journals, conference proceedings, and newspapers have been analyzed to contextualize findings and identify research gaps. The study affords suitable insights into the implications of remote work and has offered suggestions for improving its effectiveness while developing sustainability and interdisciplinary comprehension.

Keywords: Pandemic, Work from Home, Remote Work, Behavioral Dynamics, Environmental Implications





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INTRODUCTION

The pandemic has quickly changed how the world's people deal with their lives. One of the most radical shifts has been from the conventional office settings to remote work from anywhere (WFH) arrangements. While these reforms' organizational and psychological impacts have drawn extensive scrutiny, their interaction with the natural sciences is underexplored. Adjustments in conduct due to Work From Home guidelines that include changes in commuting, resource usage, and interactions with local areas and sustainability have had tremendous implications on ecological systems and sustainability. Remote work has lessened urban congestion and the associated commuting, leading to temporary reductions in air pollution and the usage of energy. However, an increase in reliance on digital technologies and home energy consumption pose new challenges to environmental sustainability. Moreover, changes in work settings impact human interactions with green spaces, wildlife, and natural resources, providing a unique opportunity to study behavioral responses within ecological frameworks. The present study focuses on how reshaping human behaviour through work-from-home (WFH) policies in the wake of the COVID-19 pandemic has branched out to include environmental and ecological implications. By bridging behavioral science with natural science, this work contributes both to a comprehensive understanding of the wider implications of remote work as well as to a foundation for sustainable route policy design and multidisciplinary research initiatives. According to a new MIT study almost half of those who were employed in organizations are now working remotely. Organizations have scrutinized their working models, work cultures, values, and having considered the changing needs of the workforce over the last couple of years, have afforded them greater autonomy and flexibility. There has been an increased trend towards work from home or remote work which has resulted in improvisations, both on the part of the employers and employees. Many company executives have witnessed for themselves that productivity can be heightened and excellent work can be achieved through remote work and many organizations including Twitter and Facebook are contemplating providing permanent work from home options to their employees.

Background to the study

Hopefully the Covid-19 is behind us. However, nearly five years ago, when the World was helplessly reeling under the dread of the COVID-19 pandemic along with the fear of rising death toll due to the lethal virus, the WHO declared the COVID 19 as a pandemic and the Government of India announced a complete lockdown. Companies began to implement work from home policy for their staff as part of encouraging social distancing to curb the menace of the pandemic. Work from home became the need of the hour for most of the working population and has now become common for many employees around the globe -(Eva Thulin, 2019) This has brought a mammoth change in the way employees work. The digital transformation and the virtual workspace have made the employees work together, despite being located in different parts of the country or across the continent.

Work from Home: Meaning and Benefits

WFH means an employee works from the house, apartment, or place of residence, rather than working from the office. This debate regarding whether WFH is a conducive work policy has been in vogue from the time the world has begun to shift towards digital technology as its principal form of consuming, with supporters of both schools of thoughts providing some conflicting yet sensible and workable contentions for their stance. All the proponents of work from home argue that the system provides their routine a much needed suppleness and flexibility. In contrast, the supporters of work from office contend that the entire objective of work from office is to construct and create an atmosphere that encourages effort and promotes teamwork.

LITERATURE REVIEW

In (Farrell, 2017) the author opined that family and work are the most significant elements of human life. (Derek H. T. Walker, 2008) opined that work-family balance is easily one of the most challenging issues that face families in the 20th century. It cannot be denied that the home plays a pivotal role in sustaining the well-being of people and society.



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Interestingly, (Friedman, 2014) stated that in order to be effective, one needs to know what is important and what matters. The author recommended an exercise called “Four circles”. This represents the four domains- namely profession/work, home, the community at large and the self. Interestingly he suggested modifying the sizes of each circle depending on the value one allocates to each. That will provide an insight into their values, goals, actions and the results thereof with respect to each area. According to (Christine A. Grant, 2013), Technology has impacted work significantly and has rendered work from home or elsewhere, a possible option. According to (Nancy B. Kurland, 1999) work has become an unbounded activity which can be carried out anytime and anywhere. In (Toffler, 1980) the author opined that the current forms of flexibility have the potential to facilitate balance between work and home. Work-life balance is often very challenging and is most times a mirage. According to (Yang Xiaoming¹, 2014) (Michael T. Ford, 2007), with respect to employees, these challenges can manifest into health issues and family difficulties. And for the employers, the results of work-home demands can result in higher rates of absenteeism, higher percentage of employee turnover and lower productivity. In (Vielhelmson et al, 2016), the author stated that work from home has become the need of the hour for most of the working population in the existing ways of work-life. In fact, the office space has now been combined with the personal space. This has resulted in bringing about a phenomenal change in the way people function. The digital transformation has facilitated team work among employees’ despite being placed at different geographical locations. According to (Jaime B. Windeler, 2017), maintaining a certain level of interaction especially social interaction is very important for smooth employee functioning, when they work from home. Wide-ranging research has been conducted earlier which has focused on the influence of work from home on the performance of employees. These include (Bailey, 2002) (Angel Martínez Sánchez, 2007) (Lilian M. de Menezes, 2011). In (Tammy D. Allen¹, 2015) (Amanda J. Anderson¹, 2014) the author opined that working from home actually lead to better performance. However, some studies by authors like (Kumar, 2022) working from home results in isolation – both professional and social that limits knowledge sharing. Due to a tremendous increase in dual earners, flexible working has assumed importance for balancing personal and professional lives (Helen Russell, 2007).

In (P.S. Reshma, P. S. Aithal, & Sridhar Acharya, 2015), the authors developed the concept of Work from Home into an E-business model that became popular due to the outbreak of the pandemic and also due to the use of digital mode. They have analyzed how office management system works on an online basis by using the ABCD analysis technique which refers to the advantages, benefits, constraints & disadvantages in the e-business model framework model. Authors (Kira Rupietta & Michael Beckmann, 2016) analyzed how working from home affects the employees. The authors used German Socio-Economic Panel (SOEP), to evaluate self-selection in working locations which they have used as a variable. Through their study they found that WFH has a positive influence on as they have autonomy and they can save operating costs due to reduced office space. (Daniel Daniel, et al., 2020) discussed the benefits of work from home such as reduced the commutation time, reduced intervention by the management, higher outcome, safety at work place as employees worked from their respective homes, very low absenteeism & higher productivity. (Amin Al-Habaibeh, Matthew Watkins, Kafel Waried, & Maryam Bathaei Javareshk, 2021) analyzed the challenges & opportunities of the IT sector during Covid-19 pandemic. They conducted a survey on the difficulties faced by the employees in using online tools, combining their working hours with daily routines. They had to face new digital experience such as online board meetings, video recordings & in process acquire knowledge for digital working. Through their study they found that employees did not have to travel when working remotely which had a positive impact. However, they also faced difficulties such as network connectivity issues. The authors discussed the self-determination theory that provides an explanation of the efficient & faster adaptation to technology. (Lina Vyas & Nantapong Butakhieo, 2020) in their article on the impact of work from home during COVID-19 conducted an exploratory study on Hong Kong and analyzed how work from home affected both employers and employees in the aforementioned country. This required changes in the policies that reshaped the structure of working hours with flexibility. Work from home became a priority policy for the Government, an exploratory study was conducted with a SWOT analysis & if work from home could be a permanent arrangement. (Chinnaiah P.M & Smt.Chyitra P., 2021) examined how work from home affects the performance & sustainability of IT sector in pandemic times. According to their study, they found seven challenges such as time management, physical infrastructure, increased mental stress, lack of good network connectivity, lack of interaction in the family, lack of support or trust from their



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superiors & lack of motivation. (Sanchez Daniel Garrote, et al., 2020) discussed the benefits of work from home such as reduced the commutation time, reduced intervention by the management, higher outcome, safety at work place as employees worked from their respective homes, very low absenteeism & higher productivity (Amin Al-Habaibeh, Matthew Watkins, Kafel Waried, & Maryam Bathaei Javareshk, 2021) have analyzed the challenges & opportunities of the IT sector during Covid-19 pandemic. They conducted a survey on the difficulties faced by the employees in using online tools, combining their working hours with daily routines. They had to face new digital experience such as online board meetings, video recordings & in process acquire knowledge for digital working. Through their study they found that employees did not have to travel when working remotely which had a positive impact. However, they also faced difficulties such as network connectivity issues. The authors discussed the self-determination theory that provides an explanation of the efficient & faster adaptation to technology. (Thomaz Teodorovicz, Raffaella Sadun, Andrew L. Kun, & Orit Shaer, 2021) in their working paper on Working from Home have tried to explore the impact of this new adaptation amongst the knowledge workers in America. The new work shift resulted in WFH arrangements, allocation of time across different activities & responsibilities & cope up with managerial responsibilities & individual contribution. They wanted to understand how human computer interaction (HCI) technology affected in terms of improving productivity, well-being, team work & social interactions. The study related to pre & post COVID days & found that there exists heterogeneity between managers & non-managers, how they could balance their work & personal life during WFH amongst knowledge workers. (Tariq Albluwi, Md Atiqur Rahman Sarker, Zubayer Abir, & Fabia Hannan Mone, 2022) conducted an exploratory study to examine the challenges & measures to improve the new policy Work from Home due to the outbreak of the pandemic from the organizations in Malaysia. Their study highlighted challenges like lack of motivation, less social life, pay cuts, low communication, mental health & slow internet connectivity. They also found that self-management was one of the challenges as there was no fixed time or specific rules for work from home.

Theoretical Background

Some of the theories that relate to the present study and to analyze the impact of work from home on performance & motivation, are discussed below. A theory on motivation that relates to satisfaction, performance & rewards is put forward by Porter & Lawler. According to them, performance is linked to a reward, it is the reward that drives motivation & performance. The theory considers factors such as value of reward, efforts, energy to execute a given task, abilities, traits & perceptions. They opined that performance leads to satisfaction. Performance which leads to satisfaction & motivation includes these aspects namely increased pay, promotion, job security & status. Another theory related to the present study is the Six Factor Model of Psychological wellbeing stated by Carol. The theory states that factors such as personal mastery, autonomy, a feeling of purposed, meaning in life, personal growth & development, positive relationship with others will cause psychological well-being of individuals. In this context, positive relationship with others implies co-workers, supervisors & colleagues, all of whom try to maintain work life balance through social exchange & feelings such as empathy, trust & respect that contribute towards the individual's & organizational growth. Maslow's motivational theory can also be related to the study. Maslow refers to a hierarchical level of psychological needs in a pyramid. Employees in an organization would aim for feeling of accomplishment, security, status apart from other basic psychological needs which include affection, belongingness & basic needs. A feeling of accomplishment & achievement will add to the organizational growth & also individual growth. Another theory by S Gundel in his theory of typology of crises where the pandemic can be categorized as an intractable crisis which means difficulty, preparedness, hard work, stress that employees had to face due to lockdown restrictions during the pandemic.

The objectives of the paper are the following

- I. To examine if the preference to work from home is gender specific and/or age specific.
- II. To study the benefits and implications of work from home policy.



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RESEARCH METHODOLOGY

This study is quantitative in nature and data is being gathered from approximately 281 respondents. A structured questionnaire was adopted to gather data. The questionnaire comprised of a total of 12 questions with six questions pertaining to demographics. Data was collected from full time employees. The answers revealed the inherent challenges involving work from home and some suggestions to overcome such challenges. The analysis revealed the hypothesized relations between age of the respondent and the notion that work from home is a conducive work policy; gender and the notion that work from home is a conducive work policy. The current research of WFH among employees in India is an attempt to assess the antecedents in current situation. These results have important theoretical and practical implications. Secondary data has been extensively used from sources like newspapers, published research articles, journals and conference proceedings available at the national and international level. Information obtained from different sources have been used for providing inputs on the subject as well as identifying research gaps in the domain of the study.

Data Analysis

Reliability Test

Cronbach Alpha reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
.796	35

We have tested reliability by using Cronbach's Alpha. Since value is 0.796 i.e., more than 0.7, we can conclude all the scale measurements had shown reliability.

Demographic Divisions

Gender of Respondents

The graph indicates that in the selected sample, there is a distribution of 56% male and 44% female participants. This distribution suggests a relatively balanced representation of gender within the sample, with a slightly majority of male participants.

Age of Respondents

The age distribution of respondents in this study is detailed in the above chart. The largest age group among the participants falls within the 36-40 years range that comprised 20% of the total respondents, with a substantial count of 56 individuals. The second largest group is in the 31-35 years range that represented 18% of the sample consisting 51 participants. Other age groups have also contributed to the data set making up smaller proportions. The cumulative total of respondents in the study is 281, provided a comprehensive overview of the age demographics within the sample.

Testing the Hypotheses

The survey method adopted in this study resulted in remarkable findings relating to the challenges and solutions of Work from Home being a Virtual reality.

Hypothesis 1

H₀: There is a no significant relationship between Gender/Age and the desire to Work from Home.

H₁: There is a significant relationship between Gender/Age and the desire to Work from Home.

Since the P value is less than 0.050, it can be inferred that the null hypothesis can be rejected and the alternative hypothesis can be accepted. This proves that there is a significant relationship between Gender as well as Age and the desire to WFH.





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Hypothesis 2

H₀: There is a no significant relationship between Gender and the advantages and difficulties linked towards Work from Home.

H₁: There is a significant relationship between Gender and the advantages and difficulties linked towards Work from Home. Since the majority of the P values is $< .001$ which is highly significant in nature, it can be inferred that there is a significant relationship between Gender and the advantages and difficulties linked towards WFH. Hence, the null hypothesis can be rejected and the alternative one can be accepted.

Findings: The following findings were revealed as per secondary data:

Biggest struggle with working remotely, according to State of Remote Report-2019.

Challenges from the employer's perspective

- Collaborating with remote team members can be incredibly challenging, especially if they don't have the right tools with them.
- Employees working from different locations and time zones.
- Building and maintaining trust.
- Tracking employee performance.

Some revealing statistics regarding WFH

In a survey conducted, it was revealed as follows:

- 90% of the Indian employees who operate from home feel that better connectivity is a must to improve efficiency.
- Around 20% of the employees faced challenges when they attempted to share large files.
- Almost 19% of the employees feel isolated and lonely after work from home option after a substantial stretch.
- Almost 7% of the employees feel tempted to take a vacation when nobody is keeping check.
- A majority of them find it hard to maintain a work-life balance.
- Majority of the employees find it rather challenging to unplug into their normal routines.
- A number of them start questioning the reasons for their work from home and end up becoming less productive.
- Perhaps all these factors contribute to rendering work from home more challenging.

Some of the prominent benefits are: Benefits to employers- Based on secondary data

- WFH can result in improved productivity than the conventional working style (Kathryn L. Fonner, 2010)(Timothy D Golden, 2005)(Nicholas Bloom, 2015)
- Reduction in turnover rate (Eleni T. Stavrou, 2010)(Nicholas Bloom, 2015)
- Reduction in organizational cost (Prithwiraj (Raj) Choudhury, 2020)
- Employees can be hired from a wider talent pool as WFH will be unrestrained from geographic conditioning.
- In case of some undesired event, such as any natural calamities, distributed workforce ensures continuity in operation and hence reduces the risks.

Benefit to employees- Based on secondary data

- It helps in reduction of commuting time:
- This is specifically important in the Indian context as its people spend on average 7% of the day in commuting (Thomson et al 2012)
- Reduced travel and other associated costs
- The lower level of stress in employees and better work-life balance(Kathryn L. Fonner, 2010)(Nicholas Bloom, 2015)
- Increased autonomy for individuals (Harpaz, 2002)
- An increase in leisure time and family time (Samantha K. Ammons, 2010)
- Increased job satisfaction (Franco Gandolfi, 2011)(Madsen, 2003)
- Less distracted by co-workers (Timothy D. Golden, 2008)



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- It helps in alleviation of pollution, especially air pollution. (Diane E. Bailey, 2002)
- It holds special importance in Indian context as 21 of the world's 30 most polluted cities are in India and vehicular pollution constitutes a major chunk of it.
- Less Traffic congestion: Indian roads are notoriously known for heavy traffic congestion. In many of its many major cities, the average time taken to reach to the workplace is highest in the world.

Findings based on secondary data

What has changed the most about your work, now that you work remotely.

Testing of the Hypothesis

There is a relationship between gender and desire to work from home. It was observed that majority of the men respondents preferred the work from home culture and considered the work from home policy more ideal. The primary reason is that work from home has proven to lower stress levels besides providing increased time to pursue hobbies, interests and improve familial relationships. Besides, one of the best aspects of work from home is the escape from the rigid and traditional 9 to 5 routine. This allows flexibility to the employees to set their own schedules. However, women find it more challenging to work from home as they are required to multi-task. When they operate from home, the thin dividing line between their professional and personal lives, gets ruptured and they end up failing to have a work life balance. It was also observed that there was a significant relationship between gender and the advantages and challenges of work from home. Some of the benefits included providing emotional support, moving towards goal-oriented KPIs, considered group communication tools to allow employees to communicate even outside core group meetings. The challenges, on the other hand included, blurred work-life boundaries, inadequate practical equipment, employees experiencing social isolation, employees experiencing the right levels of supervision without overstressing the employees in the process. Besides other challenges included, retaining employee loyalty and talent retention besides overcoming lack of trust that was demonstrated by many of the employers.

Other findings based on Literature review

- Developing Blurred Work-Life Boundaries was one of the major challenges experienced by employees with respect to WFH.
- Employee Isolation was also one of the major issues with regards to WFH.
- Ensuring the correct levels of supervision and accountability without overly stressing employees in the process was a challenge faced by the employers.

Solutions recommended – based on Primary Data:

- Providing Emotional Support
- Supervisors should avoid excessive communications outside working hours, especially for nonessential tasks.
- Employers can consider moving towards goal-oriented key performance indicators (KPIs).
- Make sure to communicate KPIs clearly and reward employees that are performing above and beyond expectations
- Distractions at Home can be overcome by avoiding taking too many breaks as that may break the workflow. That will also result in low productivity.
- It is rather important for teams as well as managers to extensively use video conferencing in order to establish face to face contact. This is in contrast to earlier when text messages or email would have sufficed for the purpose of business operations.
- It is very important to communicate when individuals work remotely.
- It is important to use platforms like Google hangouts, Zoom and Microsoft Teams on a daily basis. It is an effective method to enhance strategies for employee engagement.
- It is important to set realistic goals besides seeking feedback in order to ensure that there is inclusiveness in the organizational objectives.





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- It is essential to focus on results rather than activities. This is recognized as an essential practice to improve employee empowerment and engagement.
- It is imperative to downsize the number of zoom sessions and to avoid going overboard. It is conducive to schedule time for non-work related activities and talks.
- Mentoring is preferred as compared to managing. It is an accepted practice for managers to mentor and coach their employees rather than manage them.
- Empathy on the part of the manager is most recommended as every team member is unique and has myriad requirements. It is therefore important for every manager to be mindful and cognizant of each employee's unique situation.

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Table:1

IDV	DV	P Value
Gender	WFH being the ideal work culture	.003
Gender	WFH adversely in favor to the interests of women	.009





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Age	WFH being the ideal work culture	<.001
Age	WFH adversely in favor to the interests of women	<.001

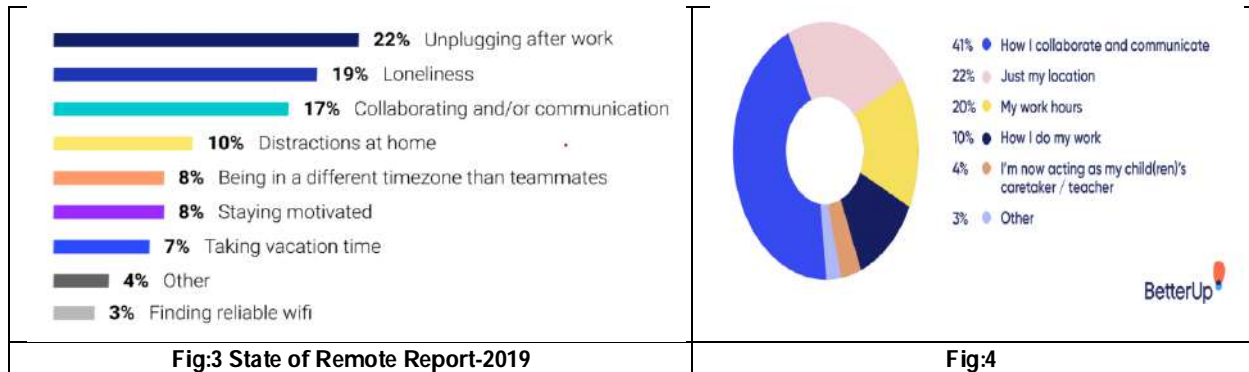
Table:2

IDV	DV	P Value
Gender	Solution of providing emotional support	<.001
Gender	Solution of employees considering equipment allowances outside core work materials	<.001
Gender	Solution of employers considering moving towards goal-oriented KPIs	<.001
Gender	Solution of considering group communication tools to allow employees to communicate even outside core meeting groups	<.001
Gender	Challenge of developing blurred work-life boundaries	<.001
Gender	Challenge of inadequate practical equipment	<.001
Gender	Challenge of Employee isolation	<.001
Gender	Challenge of ensuring the correct levels of supervision and accountability without overly stressing employees in the process.	<.001
Gender	Challenge of employee loyalty and retention	<.001
Gender	Challenge of WFH- it lacks trust demonstrated by a fair number of employers	.003





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Quadrilateral Route Factor Assessment in Manet

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ABSTRACT

Quadrilateral Route Factor Assessment (QRFA) in Mobile Ad-hoc Networks (MANETs) is a method used to evaluate the efficiency and reliability of routes in MANETs based on quadrilateral geometrical properties. In MANETs, where nodes dynamically form a network without the reliance on a fixed infrastructure, routing becomes a critical aspect. QRFA aims to assess the quality of routes considering factors like link stability, interference, and transmission range. The basic idea behind QRFA is to identify quadrilateral areas formed by nodes in the network. These quadrilateral areas can represent potential areas of contention or interference, affecting the stability and performance of routes passing through them. By assessing the properties of these quadrilaterals, such as their size, shape, and overlap with other quadrilaterals, QRFA helps in identifying routes with higher reliability and efficiency. QRFA can be used in routing protocols and algorithms to improve the selection of routes in MANETs, leading to better overall network performance and robustness against dynamic network conditions.

Keywords: Quadrilateral Route Factor Assessment, Geometrical, MANETs.

INTRODUCTION

MANETs are decentralised wireless networks where nodes can dynamically join and leave the network. Routing protocols are needed to find paths between nodes. QRFA is a routing protocol proposed for MANETs that selects routes based on hop count, energy level, mobility, and security. Each factor is assigned a weight, and routes are ranked based on a composite metric. A MANET network is a network of portable devices that can connect

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dynamically at any time and location without any fixed organisation. These devices, including laptops, smart phones, and sensors, work together to provide essential network functions in a distributed manner. One of the critical features of MANET networks is that they allow devices to move freely and autonomously in any direction, connecting and disconnecting from the network at will. However, this also means that variations in link state with other nodes are experienced regularly, posing significant challenges for routing protocols operating in MANET.

QUADRILATERALROUTE FACTOR PREDICTION TECHNIQUES

The Quadratic Route Factor Estimation technique in MANETs involves partitioning the entire network into four quarters within the geographic network region. This approach maintains route details and network information at each time frame for each specific quadratic region, providing a detailed picture of the network's performance. This technique allows routing protocols to make optimal routing decisions based on current network conditions and ensure efficient communication in MANETs. The process can be outlined as follows:

Geographic Partitioning

Divide the entire network region into four quarters based on a geographical or coordinate system. Define the boundaries of each quadrant, creating distinct areas within the network.

Time Frame Management

To ensure optimal network performance, it is essential to document route specifics and network data regularly.

Quadratic Region Analysis

To analyse the quadratic region in each quarter, it's essential to consider several key parameters such as the node count, distance between nodes, transmission range, network traffic load, and node mobility. By carefully examining these factors, we can gauge the quality of routes and tailor routing protocols to the current network conditions.

Snapshot Generation

In MANETs, it is essential to capture snapshots of the network topology and note the characteristics of each quadratic region. This approach enables routing protocols to adapt to any dynamic changes in the topology and ensure smooth and efficient communication.

Route Details Storage

Recording route details within each quadratic region is crucial in MANETs. This includes established routes, hop counts, and factors influencing routing decisions, enabling optimal routing decisions and efficient communication.

Data Persistence

Storing snapshots and route details persistently are crucial for retrospective analysis and optimising routing strategies in MANETs. Implementing a storage mechanism that allows easy retrieval of historical data enables the identification of patterns and trends, ensuring efficient communication.

Analysis and Estimation

In MANETs, collected data can be utilised to analyse the network's behaviour, route changes, and performance trends over time. Quadratic Route Factor Estimation techniques can then be applied to assess the impact of factors on route selection within each quadrant. By analysing the network's behaviour and performance, routing protocols can make optimal routing decisions and ensure efficient communication in MANETs.

Adaptation and Optimization

In MANETs, optimising routing strategies in each quadratic region is crucial. By analysing network behaviour and dynamics, routing protocols can adjust routing decisions and identify patterns and trends within the network. The QRFE technique facilitates retrospective analysis and continuous optimisation of routing strategies, ensuring efficient communication and protecting against routing attacks. To detect routing attacks in MANETs, a method analyzes the





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route trace and network snapshot at different locations. The method selects nodes based on various parameters, improving network performance and throughput ratio. By using packet information, the process can identify malicious nodes and protect against routing attacks, ensuring efficient communication in MANETs. The QRFE technique provides a solution to handle these attacks using the route factor. By computing the route factor, the QRFE technique enables routing protocols to make optimal routing decisions that ensure efficient communication and protect against routing attacks in MANETs. Figure 1 Illustrate The phases involve assessing various factors such as Route discovering quadratic zones, Exploration and Route variable Estimation. Routing protocols and models for MANETs often involve assessing or considering multiple factors or metrics, such as path length, link quality, node mobility, energy consumption, traffic load, delay, throughput, and security.

- **Destination address:** The IP address or identifier of the target node.
- **Estimated cost:** A numerical value representing the overall quality of the path to the destination, calculated using the quadratic function.
- **Next hop:** The address of the next node on the path towards the destination.
- **Additional parameters:** Depending on the specific routing protocol, the table might include other relevant data like hop count, delay, or link quality metrics.
- **Node ID:** This column identifies the node for which the route is being calculated.
- **Route:** This column shows the specific route from the source node to the destination node.
- **Hops:** This column indicates the number of hops in the route.
- **Route Factor:** This column calculates the quadratic route factor, which is the product of the squared distances between each hop in the route.

Discovering Quadratic Region

This section captures network details and generates the network topology. At each time window, the sink node performs time-oriented snapshot generation, maintaining traces of packets and location details of nodes in different regions. The sink node adapts to the frequent changes in topology due to node mobility. To support routing attack detection, maintaining an essential network topology is crucial. The generated snapshot is then updated with nodes detected in quadratic routing attacks.

Algorithm 1.1: Discovering Quadratic Region

```

Input  : Node Traces, Node Locations, Time Windows, Threshold
Output : Discover the Quadratic Region

Step1: Initialization
Initialize sensor nodes with their positions in the region.

Step2: Splitting Region into Four Quarters
Divide the region into four quarters (Q1, Q2, Q3, Q4) based on the coordinates
of the region's center or a predefined reference point.

Step3: Calculate the coordinates of the center point (Cx, Cy) of the region.
region_center = calculate_region_center(sensor_nodes)
Cx, Cy = region_center[0], region_center[1]
# Define the coordinates of the four quarters
Q1 = (Cx, Cy)
Q2 = (Cx, Cy)
Q3 = (Cx, Cy)
Q4 = (Cx, Cy)

Step 4: Assign Nodes to Quarters
Iterate through the sensor nodes and assign each node to one of the four
quarters based on its coordinates.
for node in sensor_nodes:
    x, y = node.coordinates
    if x >= Cx and y >= Cy:
        # Node is in Q1
        assign_node_to_quarter(node, Q1)
    elif x < Cx and y >= Cy:
        # Node is in Q2
        assign_node_to_quarter(node, Q2)
    elif x < Cx and y < Cy:
        # Node is in Q3
        assign_node_to_quarter(node, Q3)
    elif x >= Cx and y < Cy:
        # Node is in Q4
        assign_node_to_quarter(node, Q4)

Step 5: Quadratic Region Identification within Each Quarter:
For each time window Ti
    Identify Number of nodes present in the network region.
    
$$Nd = \sum_{i=1}^n Nodes(Ri) \cdot Ti \cdot Ri$$

    Generate topology Nt.
End
  
```





The above-discussed algorithm computes the network topology for each quadratic region being identified and used for route discovery.

Routing Exploration

The route exploration process involves calculating the feasible routes within each regional topology. The time-oriented snapshot exclusively constructs the network structure, and based on this topology, the method determines the overall count of routes accessible from the source node to the sink node. Subsequently, upon identifying the distinct routes, the method calculates the hop count for each available route. These computed routes are then employed to determine the quadratic route factor in the subsequent stage.

Algorithm 1.2: Routing Exploration

Input : Topology Set Ts: A set of network topologies.
Output : Route Table Rt: A table containing the available routes.

Step 1: Initialization
 The algorithm starts by defining its input (Ts) and output (Rt).

Step 2: Iterates through each entry in the topology set (Ts).
For Each Topology Entry Ti in Ts:
 Identify the neighbors of source node Sn
 $Ns = _Neighbors(Ti, Sn) TransmissionRange(Sn)$

For each topology entry (Ti), it identifies the neighbors of a specified source node (Sn).

Step 3: Compute Neighbors within Transmission Range
 Compute the neighbors (Ns) based on a specified transmission range of the source node (Sn).

Step 4: Compute Available Routes through Each Neighbor
 For each neighbor (Ni) within the computed neighbors (Ns), the algorithm proceeds to compute available routes.
 For Each Neighbor Ni in Ns:
 The algorithm iterates through each neighbor in the set of computed neighbors (Ns).

Step 5: Compute Routes Available
 calculates the routes available through the current neighbor (Ni).

Step 6: Add Routes to Rt
 The computed routes (Rts) are added to the overall route table (Rt).

Step 7: Update Rt
 The route table (Rt) is updated with the newly computed routes (Rts) for the current topology entry.

End

End

The algorithm concludes the loop iterating through neighbors (Ni).

The above-discussed algorithm computes the available routes in each region to perform routing attack detection.

Route Variable Assessment

The quadratic route factor is the value computed on each region according to the packet traces. The Next calculation involves analysing various aspects of the routes, including their transmission rates, payloads, hop counts, and common hops in malicious traces, to derive a comprehensive factor (QRF) that considers these metrics together. This approach involves maintaining records of transferred packets for various routes. The method calculates key





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parameters for each route, such as packet transfer rate, payload, hop count, and more. Utilising these metrics, the method then calculates the Quadratic Route Factor (QRF), reflecting the reliability of each route for packet transfer. The method incorporates a set of malicious traces containing identified packet transfers to enhance its analysis. Leveraging these traces, the method calculates the QRF value. Throughout the route discovery process, the method determines the quadratic route factor for each identified route. The computed QRF values play a crucial role in detecting routing attacks.

Algorithm 1.3: Quadratic Variable Assessment

Input: Route Table Rt, Network Trace Nt.

Output: QRF value

Step 1: Compute Transmission Frequency (Tf):

$$Tf = \frac{\sum (Traces, Ri \in Nt)}{size(Nt, Region)}$$

- This formula calculates the transmission frequency (Tf) for each route (Ri) from the route table (Rt).
- It involves summing the transmission rates (Traces, Ri) for each route in the set (Nt) and then dividing by the size of the set in the specified region.

Step 2: Compute average payload.

$$APL = \frac{\sum (Traces, Ri \in Nt), payload}{size(Nt, Region)}$$

- This expression computes the average payload (APL) for each route (Ri) in the set (Nt)
- It involves summing the payloads for each route and then dividing by the size of the set in the specified region.

Step 3: Compute average hop count AHC

$$AHC = \frac{\sum (Traces, Ri \in Nt), HC}{size(Nt, Region)}$$

This formula calculates the average hop count (AHC) for each route (Ri) in the set (Nt).

Step 4: Compute Common Hops in Malicious Trace (MCH)

$$MCH = _Hops (Traces, Ri \in MH) \cap MH$$

- This expression computes the set of common hops (MCH) present in the malicious traces (MH)
- It involves finding the intersection (common elements) of the hop sets for each malicious route

Step 5: Compute Number of matches in MCH(NM)

$$NM = \sum Ri Hops (Ri) \in MCH$$

This formula calculates the number of matches (NM) in the set of common hops (MCH). It involves summing the hop counts for each route that belongs to the common hops set.

Step 6: Compute the Quadratic Route Variable Estimation

$$\text{Compute QRF} = \frac{Tf \times APL}{AHC \times NM}$$

This expression computes the Quadratic Route Factor (QRF) by multiplying the transmission frequency (Tf) with the average payload (APL) and dividing by the product of average hop count (AHC) and the number of matches in common hops (NM).

Routing Anomaly Prevention

Addressing routing attacks involves evaluating and responding to the quadratic route factor. This entails computing the quadratic route factor for each available route. When multiple malicious routes are identified, a temporary sink node is deployed to gather data and facilitate routing attack detection. Subsequently, a route's reliability is determined by assessing the computed QRF value. The algorithm identifies and addresses routing attacks by evaluating the quadratic route factor. It calculates this factor for every available route. If multiple malicious routes are detected, the algorithm deploys a temporary sink node to collect data for routing attack detection. Subsequently, the algorithm uses the computed QRF value to determine the trustworthiness of each route, deciding whether it is safe for data transmission.



**Algorithm 1.4: Routing Anomaly Prevention**

```

Input      : Route Table Rt
Output    : Null

Step 1: Initialize Malicious Routes MRS

Step 2: Iterative Process for Each Region and Time Window
    for each region  $R_i$  in  $R_s$ 
    for each time window  $T_i$ 
    // Generate Snapshot
        Snapshot = GenerateSnapshot ()
    // Perform Route Discovery
        Routes = PerformRouteDiscovery (Snapshot)

Step 3: QRF Computation
    for each route  $R$  in Routes
        QRF = ComputeQRF ( $R$ )

Step 4: Detection and Addition to Malicious Routes
    if  $QRF > RTh$ 
        AddToMRS (MRS,  $R$ )

Step 5: Refining Malicious Routes by Region
        MRS = Union (MRS,  $R_i$ )

Step 6: Threshold Check for Sink Node Deployment
    if size (MRS) > (1/3 * size (Rt))
        DeployTemporarySinkNode ()

Step 7: Route Selection for Packet Transmission
        SelectedRoute = ChooseRouteWithLeastQRF (Routes)
        TransmitPacket (SelectedRoute)

Step 8: End of Algorithm

```

The algorithm mentioned above calculates malicious routes. If the count of malicious routes exceeds one-third of the total available routes, the approach involves deploying a temporary sink in the identified region. The method divides the entire geographic region into four quarters relative to a source node. For each quarter, the algorithm generates time-oriented snapshots and topologies. From the generated topology, the method computes available routes. Subsequently, for each route, it calculates the Quadratic Route Factor (QRF). By utilising the computed QRF values, the method assesses the trustworthiness of each node.

PERFORMANCE EVALUATION

The proposed system is implemented using Network Simulator 3. The effectiveness of the Quadrilateral Route Factor Assessment (QRFA) estimation technique is evaluated in conjunction with the AODV routing protocol under attack conditions and MOMM with attack conditions. Energy consumption should be modelled for transmit, receive and idle modes. Nodes may start with a fixed initial energy, which will deplete overtime. For QRFA, each node periodically broadcasts beacons with its current mobility and energy info. Routing tables are built at each node based on received beacons.

Analysis of Packet Delivery Ratio

In the quadrilateral route, there are 4 nodes arranged in a quadrilateral shape, with each node connected to its two adjacent nodes. Data packets take multi-hop routes along the edges of this quadrilateral. PDR depends on several factors like node mobility, transmission range, traffic load, etc. Increasing node speed and number of hops generally decreases PDR due to more frequent route breaks. In Figure 5.1, the analysis of the packet delivery ratio in the QRFA model is illustrated, showcasing variations in the number of nodes. The packet delivery ratio for AODV with attack stands at 75%, while MOMM achieves 95.5%. The proposed QRFA method exhibits an impressive packet delivery ratio of 97.5%. This outcome underscores the superior performance of the QRF method in comparison to the other two approaches. Figure 1.2 depicts the impact of node speed on the packet delivery ratio. The graph reveals that the packet delivery ratio of the QRFA method remains consistent despite changes in the number of nodes. Figure 5.3, Simulation result of Packet Delivery Ratio For quadrilateral MANET routing, moderate mobility, fewer hops, managed traffic load and optimal transmission range help achieve higher packet delivery ratios. Figure 1.4 shows the experiments to evaluate the packet delivery ratio of proposed routing protocols of QRFA such as varying node densities, mobility patterns, traffic loads, and network conditions.



**Kundalakesi et al.,****Analysis of Throughput**

Throughput ratio is an important performance metric in MANETs to evaluate the efficiency of routing protocols. It indicates the ratio of the number of data packets successfully delivered to the destination versus the number of data packets sent by the source. In quadrilateral routes with 4 hops, the throughput ratio depends on factors like mobility, traffic load, number of nodes, and routing protocol. High mobility of nodes causes frequent link breaks, which lowers the throughput ratio. Also, high traffic load causes congestion and packet drops. The number of nodes affects the availability of routes and interference levels. More nodes give more available routes but also higher interference. Proactive routing protocols like OLSR tend to perform better than reactive protocols like AODV regarding throughput ratio in quadrilateral routes. OLSR maintains fresh routes while AODV suffers from route discovery delays. Figure 1.5 depicts the assessment of throughput within the QRFA estimation model, considering different node quantities. In this analysis, AODV with attack exhibits a throughput of 650kbps, while MOMM with attack achieves 1800kbps. Notably, the QRFA with attack attains a superior throughput of 2250kbps. This figure underscores the enhanced performance of QRFA compared to other methods, emphasizing its capability to receive or forward packets exclusively from trusted nodes. Figure 1.6 illustrates the impact on throughput as node speed varies. The outcomes reveal a slight reduction in system throughput when AODV is under attack. Conversely, in the QRFA model, the variation in throughput is negligible even with an increase in node speed. Figure 5.7 illustrates the Simulation result of the Throughput Ratio of QRFA, Optimizing factors like node mobility, network density, traffic load, and routing protocol is key to achieving a high throughput ratio in quadrilateral multi-hop MANET routes. Figure 1.8 shows a metric used to measure the rate of successful message delivery in a network. It is calculated as the ratio of the number of received packets to the number of transmitted packets.

Analysis of Control Overhead

Based on the insights from Figure 5.8, it is evident that the control overhead in the QRFA scheme is lower than that in the AODV under attack scheme. This reduction is attributed to the QRFA method effectively minimizing the transmission of unnecessary control packets through its attack mitigation mechanism. Specifically, the control overhead for AODV under attack is recorded as 25000 packets, while MOMM with attack shows 18000 packets. In contrast, the QRFA method significantly decreases control overhead to 14000 packets. Figure 1.9 illustrates the correlation between node speed and control overhead. As the speed of nodes increases, there is an observed rise in control overhead. This increase is attributed to the potential for route failures when node speed is higher. In such cases, broadcasting routing messages becomes essential to identify new paths for transferring packets from the source to the destination. Figure 1.10 illustrates a Simulation result of control overhead can become substantial for large dynamic networks. However, it provides redundancy and robustness against frequent topological changes and link failures in MANETs. QRFA parameter tuning and optimization techniques can help reduce the routing overhead.

Analysis of Collision Rate

The collision rate of the QRFA method has been decreased to 4.33%. In contrast, the collision rate for AODV under attack is 8.23%, and for MOMM with an attack, it is 5.63%. As illustrated in Figure 1.11 and Figure 1.12, it is apparent that the collision rate of QRFA is lower when compared to AODV under attack and MOMM with attack. This reduction is attributed to the ability of QRF to eliminate collisions by identifying the QRFA factor. Stable high-quality routes selected by QRFA reduce the latency in data transmission, thereby decreasing end-to-end delays. Figure 1.13 illustrates the Simulation result of the Collision Rate of QRFA, The Collision rate increases exponentially with node density.

Analysis of End-to-End Delay

To analyze the average end-to-end delay for the quadrilateral route discovery process. The model considers factors like the number of nodes, node mobility, node transmission range, and network area. End-to-end delay is defined as the time from the origination of a route request packet to the reception of the first route reply packet at the source node. The analysis shows that end-to-end delay increases with an increase in node mobility and number of nodes. Figure 1.14 and Figure 1.15 illustrate that the end-to-end delay significantly increases in the AODV under attack



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scenario. In this case, malicious nodes broadcast counterfeit routing messages to a source, leading the source to send all packets to these malicious nodes. Subsequently, these nodes may either drop the packets or transmit them to the destination after modifying their contents. This process introduces unnecessary delays during data packet transmission. However, the proposed QRFA system effectively reduces the delay to just 0.32 seconds. Figure 5.16 illustrates the Simulation result of end-to-end delay across a quadrilateral MANET route can be expected to be higher than a direct source-destination route, with the difference depending on specific parameters like node speed, number of hops, traffic load and routing protocol.

CONCLUSION

This chapter has introduced the Quadrilateral Route Factor Assessment (QRFA), a sophisticated model designed to detect and mitigate routing attacks in network systems. The QRFA model is composed of several integral phases, which include the identification of the quadratic region, exploration of potential routes, assessment of quadratic route variables, and the mitigation of routing attacks. The performance of the QRFA model is evaluated against two scenarios: the Ad hoc On-Demand Distance Vector (AODV) protocol under attack and the Multi Optional Moderation Method (MOMM) under attack. This comparative analysis provides a comprehensive understanding of the QRFA model's effectiveness. The results of the performance evaluation reveal significant improvements in various key metrics when the QRFA model is implemented. The Packet Delivery Ratio, a measure of the successful delivery of packets to their destination, sees an increase of 20.5%. The network's throughput, which measures the rate of successful message delivery over the communication channel, also sees a substantial increase, reaching 2200 kbps. Furthermore, the QRFA model manages to reduce the Control Overhead to 14,000 packets, indicating a decrease in the total number of control packets sent during the simulation. The Collision Rate, which measures the instances of packets colliding and being discarded, is reduced to 4.33%. The End-to-End Delay, which measures the average time taken for a packet to traverse the network from source to destination, is reduced to 0.32 seconds. Most notably, the QRFA method achieves an impressive Packet Delivery Ratio of 97.5%, demonstrating its effectiveness in ensuring the successful delivery of packets within the network. In conclusion, the results highlight the superior performance of the QRFA method across various performance metrics, highlighting its effectiveness in detecting and mitigating routing attacks. This chapter provides a solid foundation for understanding the QRFA model and sets the stage for further discussions on its applications and implications in subsequent chapters.

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Table 1: Quadratic Route Factor Estimation (QRFE)

Destination Address	Estimated Cost	Next Hop	Hop Count	Delay	Bandwidth	Signal Strength
192.168.1.10	0.42	192.168.1.2	2	50 ms	2 Mbps	-70 dBm
192.168.1.11	0.46	192.168.1.1	2	55 ms	2 Mbps	-70 dBm

Table 2: Quadratic Route Factor (QRF)

Node ID	Route	Hops	Route Factor
1	1 -> 2 -> 3	2	$(\text{Distance}(1, 2) ^ 2) * (\text{Distance}(2, 3) ^ 2)$
2	1 -> 3	1	$\text{Distance}(1, 3) ^ 2$
3	2 -> 1	1	$\text{Distance}(2, 1) ^ 2$

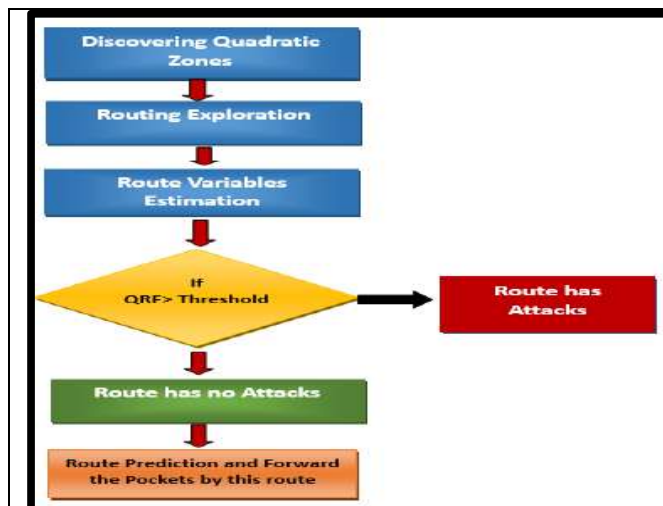


Figure 1: Phases of Quadrilateral Route Factor Assessment Model

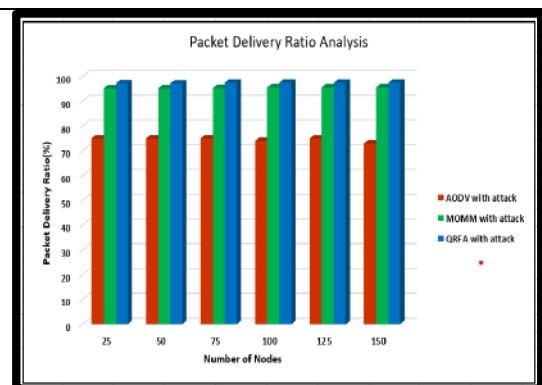


Figure 2: Evaluating Packet Delivery Ratio across Different Node Counts

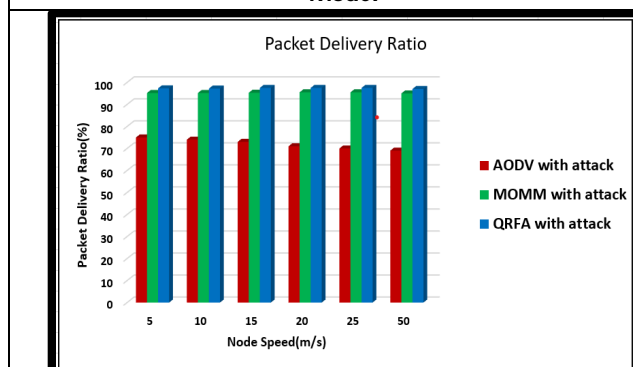


Figure 3: Analysing Packet Delivery Ratio with Varied Node Speeds

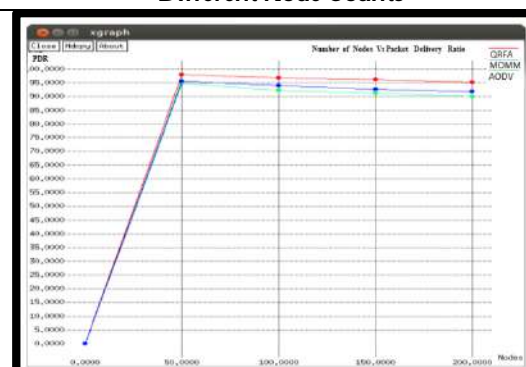


Figure 4: Simulation Result of Packet Delivery Ratio of QRFA



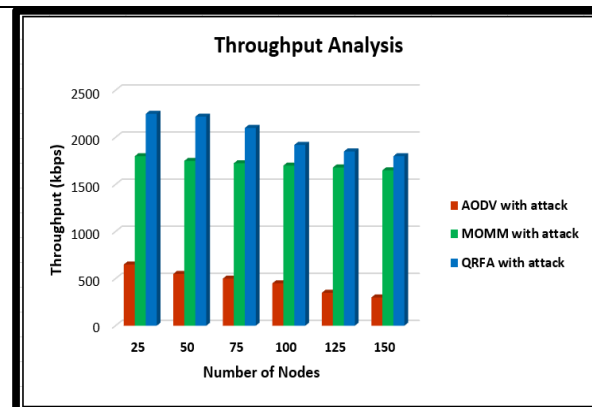


Figure 5: Evaluating Throughput Across Different Node Counts

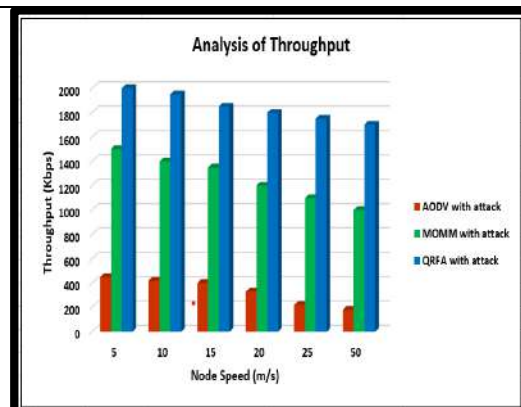


Figure 6: Analysing Throughput with Varied Node Speeds

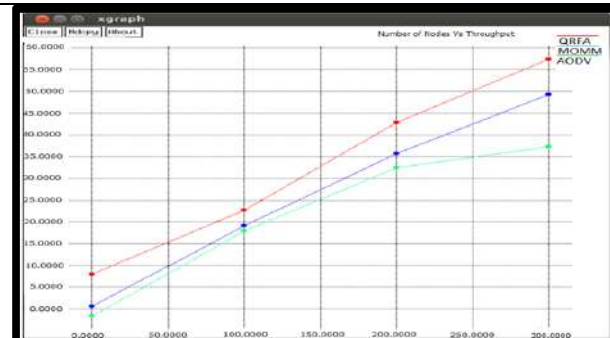


Figure 7: Simulation Result of Throughput Ratio of QRFA

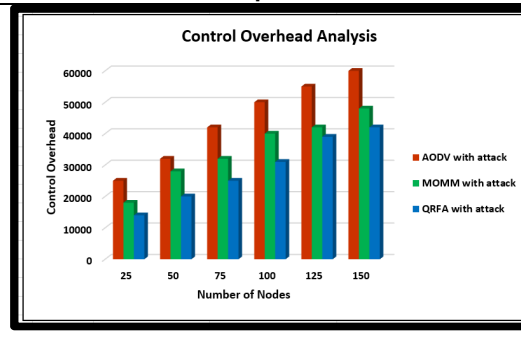


Figure 8: Evaluating Control Overhead Across Different Node Counts

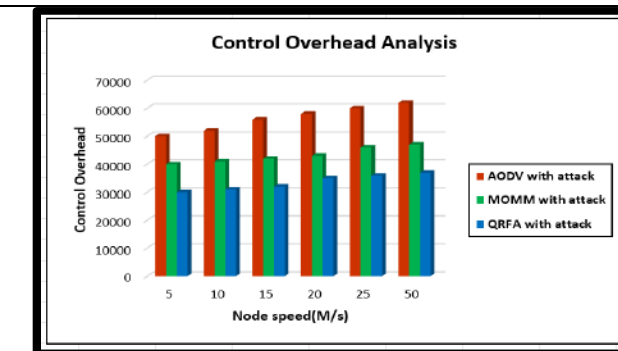


Figure 9: Control Overhead with Different Node Speed

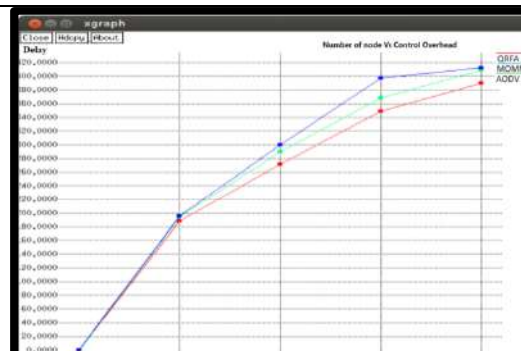


Figure 10: Simulation Result of Control Overhead of QRFA



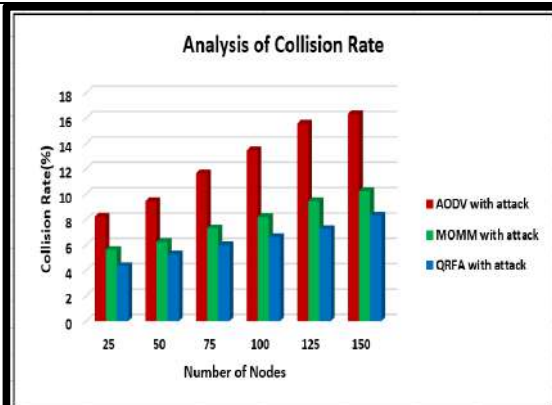


Figure 11: Performance of Collision Rate with Varying Number of Nodes

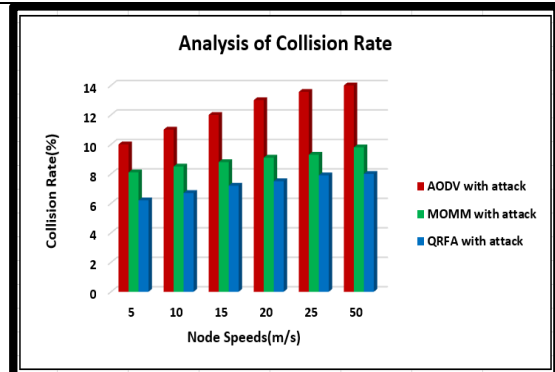


Figure 12: Performance of Collision Rate with Varying Node Speed

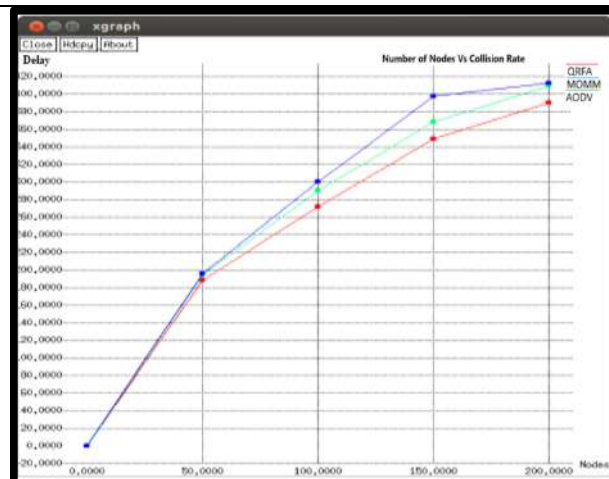


Figure 13: Simulation Result of Collision Rate of QRFA

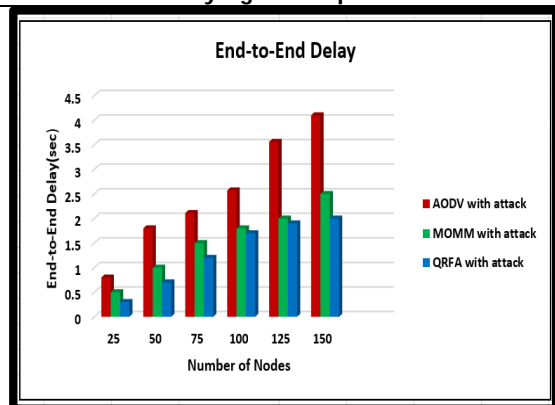


Figure 14: Performance of End-to-End Delay with Varying Number of Nodes

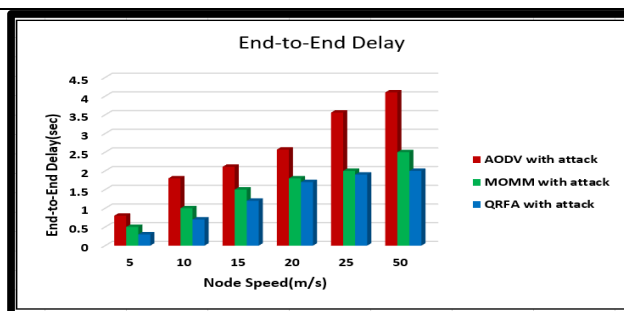


Figure 15: Performance of End-to-End Delay with Varying Node Speed

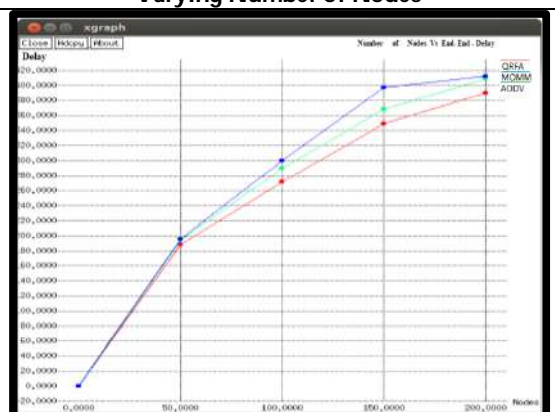


Figure 16: Simulation Result of End-to-End Delay of QRFA





Travel Time Analysis on a Road Network of Signalized Intersection

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ABSTRACT

World over the existing road network is under tremendous stress due to ever increasing surge in vehicular traffic on account of rapid urbanization and industrialization. Major cities of world such as Gandhinagar City of Gujarat state of India has been facing the menace of excessive number of vehicles plying on its roads. As the scenario continues, it becomes more than imperative to devise apt traffic signals for urban junctions of arterial and sub-arterial roads with a view to manage and regulate the vehicular flow. The present study attempts to explore the relationship between observed and calculated vehicular delays at intersections through traffic signals using a novel technique of time-space diagram. The study proposes an innovative approach for monitoring traffic volume and its spot speed, actual travel time during peak and off-peak hours, and existing traffic signal timing across the road network of Gandhinagar City. The study analyzes CCTV footages for scanning vehicle at various intersections to determine actual journey duration and delay during peak and off-peak hours. Linear Regression Model is developed to help design and devise traffic signal timings at various urban intersections. The proposed methodology has the potential to be successfully utilized for designing coordinated traffic signaling systems in urban areas within the state and country.

Keywords: Calculated Delays, Gandhinagar, Signalization, Traffic Flow, Urbanization.



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INTRODUCTION

Traffic congestion, a complex problem in urban areas over the years has been a matter of great concern for the stakeholders such as traffic engineers, traffic planners, transport department, traffic police, road users and the policymakers, not only in the developing countries but also in the developed world. Indian cities too, are typically characterized by the menace of traffic congestion. The congestion on road due to automobile traffic not only creates road rage but it has a great negative effect in terms of increased travel cost and time, adverse effects on mobility and accessibility besides the reduction in productivity. The environmental aspects of air pollution and global warming can also be attributed to traffic congestion [1]. In order to improve the overall efficiency and sustainability of a transportation system, it becomes imperative for the decision-maker to identify and quantify the traffic congestion [2]. In spite of numerous remedies which are tested out and applied on-site the research evidence suggest that the traffic congestion still remains a bigger threat more particularly in the realm of rapid urbanization and industrialization. Road traffic control strategies have always been regarded as the most viable remedy for vehicular congestion on road. Advanced traffic advisory system that employs CCTVs and sensors are currently being employed in the developed world to manage the traffic congestion. Most recently countries like Japan are employing Adaptive Signal Technologies (AST) to adjust the amount of time for a green light on a traffic signal based on real time traffic updates. This technique was developed with a view to reduce or minimize the traffic delay at intersections and has helped Japan to reduce its traffic congestion by 35 percent. Majority of the Indian cities still operate old-fashioned fixed-time signal controlling strategies to deal the traffic. This leads to poorly optimized and maintained traffic operations on roads. Complete elimination of traffic congestion is unrealistic. However, on-road deployment of advanced and efficient traffic control strategies, with a view to addressing the traffic congestion is the need of the hour. Signalizing the intersections of arterial/sub-arterial streets to control and regulate the traffic in more and more urban areas calls for systematic study of typical traffic characteristics of the region. Traffic delay study is still the most important aspect for any signal system may it be adaptive or not. This study presents a novel method to estimate the traffic delay within a network capable of handling the problems of traffic scenario at a typical intersection. The proposed approach could be significantly used by the traffic authorities for evaluating and operating the traffic signals under the current and future urban scenarios.

RELEVANT PREVIOUS WORK

Estimation of traffic delay has been historically done by several means such as photographic technique method as demonstrated by the work of Green shields et al. (1935) [3]. The authors had put forth the method of obtaining overall speeds over a stretch of highway by recording the tag number of the vehicle entering the stretch and checking the same tag number on leaving. Besides this, other methods like floating car method, license plate method, interview technique method and elevated observation methods are some of the commonly resorted techniques to study the delay. With the introduction of GPS techniques and video graphy techniques the task of data collection for delay studies has become relatively easier. Over the past six decades many delay models have been developed by numerous researchers. In 1952 Wardrop had given mathematical expression with assumption that vehicle enters the intersection with uniform arrivals [4]. Subsequently, researchers like Newell (1956) [5], Webster (1958) [6] and Miller (1968) [7] had developed representative mathematical models to estimate delay at signalized intersections which was subsequently numerically compared by Hutchinson (1972) [8], Cronje (1972) [9] and Sosin(1980) [10]. Cronje (1983) [11] had taken into consideration traffic flow at signalized intersection as a Markov process and went on to develop delay models for under-saturated and over-saturated situations. Brilon and Wu (1990) [12] used Markov chain approach for estimation of delay at signalized intersection for both poisson & non-poisson conditions. Van (1991) [13] in his study attempted to evaluate the work of Miller (1968), Newell (1956) and Hutchinson (1972) which was in form of modifications to Webster's (1958) delay expression. He found that the model proposed by the Hutchinson outweighed the other previous models of Miller and Newell by providing significant improvement in delay estimation. Tarko et al. (1994) [14] studied signal intersection approach under the influence of upstream signal for estimation of overflow delay. Heidemann [15] and Olszewski [16] had employed queue lengths probabilities to estimate delay probabilities at signalized intersections. Delay estimation analytical models for signalized intersection



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have three delay components. Firstly, uniform delay, secondly, random overflow delay, and lastly continuous overflow delay. On one hand, Hurdle (1984) [17] had suggested modification to Webster's (1958) expression based on uniform delay, on the other hand Akcelik (1981) [18] had used overflow delay component as a function of average overflow queue. Kimber and Hollis [19-20] (1978 & 1979) proposed time dependent delay deterministic model using coordinate transformation technique. Akcelik(1980) [21] also proposed Australian Delay Model for signalized intersection. Further, one more model commonly referred to as 'The Canadian delay model' was derived by Whiting (1991); Highway Capacity Manual (H.C.M.) commonly used to estimate delay at signalized intersections is also a time dependent delay model [22]. Benekohale et al. (2001) [23] presented the development and validation of uniform delay models for coordinated signalized intersections. Akgungor(2007)[24] in his study presents a new methodology for estimating delay parameter k and proposes an analytical delay model for signalized intersections that considers the variation in traffic flow. Saha et al. (2017) [25] had proposed a new model by modifying the existing HCM model. Bagdatli et al. (2020)[26] employed gene expression programming(GEP)which is an artificial intelligence technique that was used to obtain models that can estimate vehicle delays rapidly and quite accurately. Bagdatli et al. (2021) [27] in their study, developed estimation models using four different machine learning methods support vector regression (SVR), random forest (RF), k nearest neighbor (k NN), and extreme gradient boosting (XGBoost).

Patel et al. (2022)[28] conducted a comprehensive study on the optimization of traffic signal coordination at urban intersections, focusing on minimizing overall traffic delay through adaptive signal control strategies. Their research highlighted the importance of real-time traffic data and the potential of artificial intelligence in enhancing signal coordination systems. Kadiya and Varia (2010) [29] focused their research on developing a methodology for two-way coordination of traffic signals in urban corridors. Their approach involved optimizing signal control parameters such as cycle length, green split, phase sequence, and phase offset to ensure efficient traffic flow. The study likely employed traffic simulation models and real-world data to validate the proposed methodology. Shah et al. (2013) [30] focused their research on pre-timed traffic signal coordination approaches used in urban corridors. They identified limitations such as fixed timing plans and the inability to adapt to dynamic traffic conditions. The paper proposed a novel approach incorporating factors like the disutility index (a measure of driver frustration), simulation software, and potentially soft computing techniques (flexible and adaptable algorithms) to create more responsive and efficient signal coordination. Shah et al. (2018) [31] focused their research on developing a model to optimize traffic signal coordination in urban areas. This model considered factors such as intersection geometry, traffic demand, and travel times to create phase plans that minimized congestion. The model was applied to real-world scenarios, demonstrating its effectiveness in improving traffic flow. This research provides a valuable foundation for understanding traffic signal coordination and potential improvements. Traffic congestion is problematic in urban areas worldwide, impacting the commuters and the inclusive efficiency of any transportation systems. In cities like Gandhinagar, traditional fixed-time signal control methods are insufficient for handling the rapidly changing traffic conditions driven by urbanization and increasing vehicle numbers. While early methods for estimating traffic delays focused on smooth traffic flow or less congested intersections, they do not adequately address the complexity of modern traffic scenarios. Later advanced models improved delay estimation but still struggled under high-congestion conditions. In recent years, researchers have introduced new methods that incorporate factors like intersection geometry and traffic demand into delay models, aiming for more accurate signal coordination. However, The need for this study arises from the limitations of existing models and the unique traffic conditions in Gandhinagar, where mixed traffic and unpredictable congestion patterns demand a more practical and adaptable approach. This paper aims to fill the gap by developing a novel methodology for estimating travel time at signalized intersections without relying on complex simulations. While this study cost-effective methodology for estimating travel time and helping optimizing four-way traffic signal coordination. By minimizing reliance on expensive technology and focusing on low-cost transportation measures, this approach offers a more affordable solution for improving traffic flow in urban areas.





METHODOLOGY

On the congested network when the traffic flow on four directions (all approaches of four-armed junction) is heavy, four-way coordination is desirable to provide minimum delay to the vehicles. If the intersections are close (less than 1000 m), it is advisable to adopt equal signal cycle time and equal phase time on each intersection to avoid unnecessary delay to the vehicles and also to provide smooth uninterrupted flow pattern in all directions. On these lines, the present study proposes the following methodology as shown in Fig.2. The study employed a systematic approach for analyzing peak traffic volume and vehicular travel time within the Gandhinagar city. For determination of peak hours of traffic flow traffic volume data for all roads within the study area was collected for one week. Subsequently, footages of CCTV installed by Gandhinagar municipal corporation (GMC) were then obtained and analyzed for identification of peak hours and categorization of vehicular movement based on the direction of vehicular transit. With a view to derive total travel time during peak and off peak hours vehicle number plate scan records obtained through CCTV footages were used. For accurate depiction and analysis of vehicular data time space relationship were drawn and diagrams generated using AutoCAD software were developed. Figure.3 one such time space diagram used for calculation travel time for a particular road junction under consideration. The developed time space diagram enables precise measurement and comparison of vehicle's travel time against the actual recorded travel time. These diagrams along G2-GH2-CH2 route enabled analysis of traffic signal cycle. The inclination of lines as represented in the AutoCAD generated time-space diagram depicts vehicles' spot speed average over an interval of 10 minutes. This helped visualize speed variations and signal co-ordination along the road. The average travel time as experienced by a particular vehicle was computed using time-space diagram now drawn for all categories of vehicles. Travel time records obtained from CCTV footages were compared with the average travel time as derived from the AutoCAD generated time-space diagram. Linear regression model was developed for prediction of travel time based on AutoCAD generated time-space diagram. The predicted travel time was compared with recorded travel time. Root mean square (RMSE) and R^2 statistic was used for the validation of developed linear regression model. The model predictive capability is indicated by high R^2 value and low RMSE.

STUDY AREA

Gandhinagar City the capital of Gujarat is located at 23.2156° N, 72.6369° E (Figure 1). The city comprises thirty sectors, and it is a highly structured city with a well-ordered street grid comprising blocks that are divided by two types of streets that resembles to U.S. avenues and streets. The city roads are named and numbered using vernacular letters. The city has "letter roads" (K, KH, G, GH, CH, CHH, and JA) and "number roads" (1, 2, 3, 4, 5, 6, and 7). The letter roads run parallel across the city perpendicular to the number roads, and both of the road types intersect each other to form a grid, with each block or square in the grid given a sector number as shown in Figure.1 Gandhinagar is a well-organized city comprising of various rectangular sectors divided by various main, arterial and sub-arterial roads. Gandhinagar is a great site for studying traffic signal synchronization attributable to its well-organized road web. There are 21 traffic signal stations across the city which provides an ideal set-up for studying traffic flow and signal synchronization. Gandhinagar has CCTV cameras at all major crossroads facilitating collection of precise real-time traffic data. Moreover, the grid-like road network easily enables development of traffic models for analyzing vehicular movement across the city. These features and availability of traffic volume statistics and the records of vehicular license plate scan make the city an ideal location for evaluating traffic signal coordination at the network level.

DATA COLLECTION AND ANALYSIS

Data Collection

To investigate signal coordination and travel time at signalized intersections in Gandhinagar, a structured data gathering method was created, with a focus on peak hour traffic. Traffic volume data was collected for a one-week



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period during both the morning and evening peak hours, using traffic sensors placed at pertinent intersections across the city. High-definition CCTV footage was collected from Gandhinagar Municipal Corporation (GMC) cameras stationed at necessary intersections for analyzing vehicle movement patterns and determine halt durations at traffic signals during peak periods. In addition, automatic license plate recognition was utilized for tracking vehicles at various locations around the road network, enabling travel periods between intersections to be calculated. Data on signal cycle lengths, phase splits, as well as coordination mechanisms was gathered from road signal controllers.

ANALYSIS

Regression analysis and statistical processing were used to examine the collected data in order to assess how effectively signal coordination functioned. The study area's vehicle distribution during peak hours was established via traffic flow examination, which also revealed regions of bottlenecks and differences in traffic flow amongst intersections. In an effort to study the implications on travel durations and vehicle delays, traffic signal controllers provided details regarding phase splits, coordination tactics, and traffic signal cycle lengths. Time-space diagrams were drawn using AutoCAD software to reflect and indicate vehicle movement, as seen in figure. 3. Figure 3 demonstrates coordination of traffic signals across the G2, GH2, and CH2 road junctions, focusing on four green bands that represent green signal phases allowing vehicular movement. The dark band marked with 1 commences at G2 junction at zero second and lasts for 20 seconds. This would allow vehicles to proceed toward GH2 junction, where they would experience a 17-seconds delay due to the next green phase starting after 7 seconds. The spot speed was averaged over 10 minutes and is nearly 15.280 m/s between G2 junction and GH2 junction. Whereas, the spot speed between GH2 junction and CH2 junction is 15.380 m/s. The dark band marked with 1 begins at GH2 junction at the 80 seconds mark and ends at the 95 seconds mark, allowing vehicles to reach CH2 junction only by the 133rd seconds mark. Conversely, the last 3 seconds of the green band face a 104.50 seconds delay for the vehicles exiting CH2 junction. The succeeding dark bands, marked with 2, 3, and 4, signify future cycles for nonstop forward movement. Travel times among intersections were calculated approximately by vehicle number plate scan data and the same was compared to theoretical travel time. A linear regression model was developed to analyze the relationship between these travel times, with performance of the developed model measured by R^2 and RMSE. The developed model was validated using peak hour data, and its exactitude was evaluated by comparing predicted and actual travel times. The time-space diagrams not only helped visualize vehicle speeds but also helped gauge signal coordination efficiency. The linear regression models were generated for all road junctions with peak hour data and was subsequently validated using RMSE. This thorough examination delivered valuable insights into traffic flow at these junctions and enabled informed traffic management and planning.

DISCUSSION

The exploration involved fitting linear regression models to the actual travel time data and the calculated travel time data achieved from the time-space diagrams. The presentation of these models was evaluated using R^2 values, indicating the fraction of variance in the actual travel time explained by the calculated travel time. As shown in Figure 4, the linear trend analysis for both forward and backward directions is accompanied. This analysis is performed for all junctions in the study. The results are detailed in Tables 1 and 2, highlighting the models' efficiency in different time slots and directions.

Linear Regression Model Performance

Forward Direction

During the morning peak hour, the R^2 values fluctuated from 0.844 to 0.945 across various road links, with regression equations screening a strong linear affiliation. The uppermost R^2 value of 0.945 was observed for the G2-GH2-CH2 road link, signifying high model accuracy.



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For the evening peak hour, the R^2 values fluctuated from 0.722 to 0.932. The G3-GH3 link exhibited the uppermost R^2 value of 0.932, indicating a consistent model to fit, whereas the G3-GH3-CH3 link had the lowest R^2 value of 0.722, reflecting a moderate fit as shown in Table1.

Backward Direction

In the morning peak hour, the R^2 values fluctuated from 0.862 to 0.980. The CH3-GH3-G3 link reached the highest R^2 value of 0.980, signifying an excellent model to fit. During the evening peak hour, R^2 values fluctuated from 0.806 to 0.991, with the CH3-GH3-G3 link again screening the highest R^2 value of 0.991, underscoring the model's exactness. These results designate that the linear regression models generally executed well, with most R^2 values above 0.8, suggesting a strong correspondences between the calculated and actual travel times as shown in Table2. The points on the graphs represent individual observations where the calculated total travel time from the AutoCAD time-space diagram is plotted against the actual observed travel time for various road links during morning and evening peak hours in the forward direction. Each graph includes a linear regression line, which shows the relationship between the calculated and actual travel times. The closer the points are to this line, the more accurate the calculated times are in predicting the actual travel times. The results indicate a strong correlation between the predicted and observed times, with the data points generally clustering closely around the regression lines. This suggests that the AutoCAD time-space diagram is effective in estimating travel times across different road segments during peak traffic periods, making it a reliable tool for traffic planning and management. The consistent alignment of points along the regression lines for both morning and evening peak hours further confirms the accuracy of these predictions across various scenarios. As shown in Table 1, the data illustrate how closely the travel time predicted by AutoCAD time-space diagrams (x) matches the actual travel time observed (y) for the forward direction on specific road links during peak hours. The linear regression equations and R^2 values in the table help measure the accuracy of these predictions. Similarly, as shown in Table 2, the analysis focuses on the backward direction, using data from the same road links during peak hours. The equations and R^2 values in this table demonstrate how closely the predicted and actual travel times align, allowing us to evaluate the reliability of the time-space diagrams in both directions. Overall, these tables give a clear view of how well the time-space diagrams work in estimating travel times on different road links during busy traffic periods. (Where, x = Travel time in seconds obtained by Time-space diagram, y = Actual observed travel time in seconds)

Validation of the Linear Regression Model

To evaluate the developed linear regression models, 30-minute data samples from morning and evening peak hours (Table 3) were utilized. Predicted travel times based on regression equations were evaluated against actual travel times. The models' accuracy was then calculated using Root Mean Square Error (RMSE). Figure 5 exhibits the RMSE values for both directions.

RMSE Analysis

To compute the RMSE values, the actual travel times for individual 10-minute segments were recorded as the average travel time of vehicles in each section of the study area. A linear regression model was applied to calculate the overall travel time for each route stretch. The RMSE values were derived by comparing the anticipated trip durations from the regression model to the observed values. The resulting RMSE values, shown in Table 4, indicate the model's performance across various road segments and time periods. Lower RMSE values suggest a tighter match between predicted and actual travel times, whilst larger values indicate greater discrepancies, highlighting regions where the model's predictions may be erroneous. The morning peak hour validation results showed a close configuration between predicted and actual travel times, with a few discrepancies. Evening peak hour validation revealed similar small differences, indicating that the model performed accurately. Backward Direction RMSE values such as Morning peak hour results validated the model with minor differences, indicating high accuracy. Evening peak hour validation revealed minor variations, confirming the model's robustness, as illustrated in Figure 5. The developed linear regression models' high R^2 values and low RMSE values exhibits their worth in calculating travel times based on time-space diagrams. The forward direction models indicated slightly lower R^2 values in some cases through the evening peak hours, suggesting potential variability in traffic conditions. In contrast, the backward





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direction models consistently confirmed high accuracy, particularly for the CH3-GH3-G3 road link. Rigorous methodology and thorough analysis as adopted in the present study provided a comprehensive grasp of traffic flow distribution and travel time prediction for an urban scenario. These insights are indispensable for operative traffic management and planning strategies, enabling informed decision-making and optimization of traffic flow for a congested road network. Future research could explore the incorporation of other variables or advanced modeling techniques to further improve models' prediction accuracy.

CONCLUSION

The present study delved into the complexities of travel time analysis at signalized intersections within Gandhinagar city of Gujarat State, India. The study developed a novel methodology that assimilates time-space diagrams and linear regression models to effectively estimate and analyze vehicular travel times. The experimental results, characterized by a strong correlation ($R^2 > 0.8$) between calculated and observed travel times, evidently validate the usefulness of the proposed method in real traffic environments. The practical insinuations of this study extend well beyond the academic realm and offer valuable insights into traffic management strategies for urban set-up. The present study underscores the potential to ease delays and substantially augment the overall efficiency of urban traffic emphasizing the need to have coordinated signal timings for congested road networks.

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Table 1: Peak Hour Forward Direction Linear Regression Equation and R² value

Time Slot	Link of Road G2-GH2-CH2	Link of Road G2-G3	Link of Road GH2-GH3	Link of Road CH2-CH3	Link of Road G3-GH3-CH3
Morning Peak Hour	y = 0.861x + 24.01 R ² = 0.945	y = 0.809x + 7.18 R ² = 0.844	y = 1.051x - 6.584 R ² = 0.917	y = 0.784x + 23.02 R ² = 0.942	y = 0.823x + 2.74 R ² = 0.887
Evening Peak Hour	y = 0.865x + 25.12 R ² = 0.829	y = 0.963x + 1.925 R ² = 0.890	y = 0.841x + 15.57 R ² = 0.932	y = 0.721x + 1.36 R ² = 0.867	y = 0.829x + 5.16 R ² = 0.722

(Where, x = Travel time in seconds obtained by Time-space diagram, y = Actual observed travel time in seconds)

Table 2: Peak Hour Backward Direction Linear Regression Equation and R² value

Time Slot	Link of Road CH2-GH2-G2	Link of Road G3-G2	Link of Road GH3-GH2	Link of Road CH3-CH2	Link of Road CH3-GH3-G3
Morning Peak Hour	y = 0.804x + 35.44 R ² = 0.873	y = 0.742x + 22.58 R ² = 0.862	y = 1.289x - 29.55 R ² = 0.875	y = 0.847x + 14.08 R ² = 0.890	y = 0.866x + 21.54 R ² = 0.980
Evening Peak Hour	y = 1.003x - 2.773 R ² = 0.806	y = 0.799x + 18.28 R ² = 0.881	y = 0.896x + 8.700 R ² = 0.843	y = 0.946x + 3.986 R ² = 0.919	y = 0.925x + 11.11 R ² = 0.991

(Where x = Travel time in seconds obtained by Time-space diagram, y = Actual observed travel Time in seconds)





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Table 3 Validation result for Road link (G2-GH2-CH2)

Input AutoCAD calculated average travel Time (sec) (x)	Linear Regression Equation	Calculated projected travel time (sec) (y)	Actual observed avg. time taken by vehicles (Sec)	RMSE
Forward direction morning				
198	y = 0.861x + 24.01	194	194	0.46
197		194	193	
195		192	192	
Forward direction evening				
194	y = 0.865x + 25.12	193	195	2.1
195		194	191	
194		193	194	
Backward direction morning				
179	y = 0.804x + 35.44	179	177	3.09
170		172	168	
158		162	160	
Backward direction evening				
185	y = 1.003x - 2.773	183	184	2.75
174		172	176	
188		186	184	

Table 4: Forward and Backward Direction RMSE Values

Forward Direction RMSE Value					
Timing	G2-GH2-CH2	G2-G3	GH2-GH3	CH2-CH3	G3-GH3-CH3
Morning	0.46	2.90	1.97	2.14	2.64
Evening	2.10	2.90	0.86	2.79	3.14
Backward Direction RMSE Value					
	CH2-GH2-G2	G3-G2	GH3-GH2	CH3-CH2	CH3-GH3-G3
Morning	3.09	1.57	2.55	1.06	1.93
Evening	2.75	0.87	1.85	1.96	4.52





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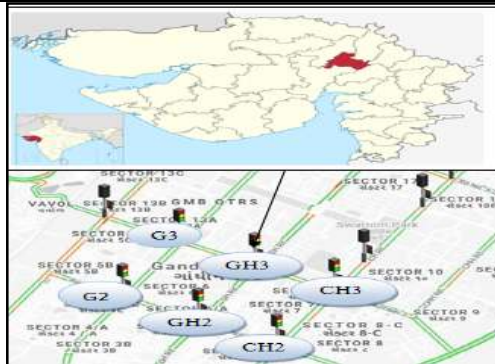


Figure 1 Gandhinagar City

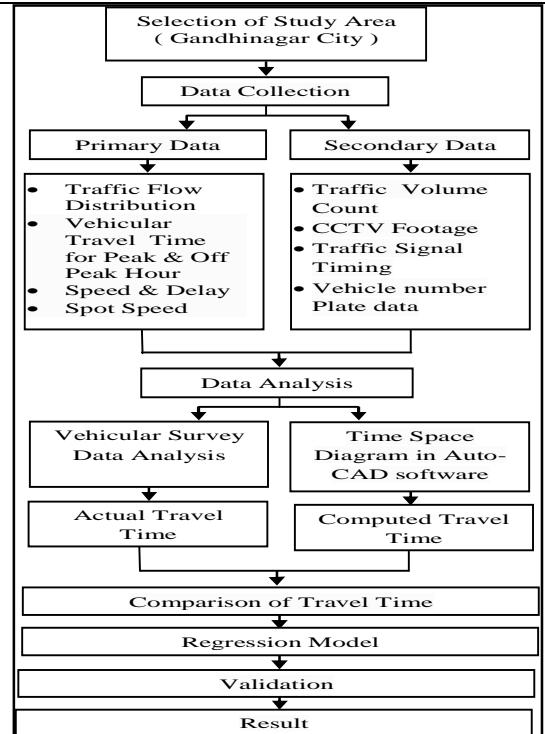


Figure 2 Research Design

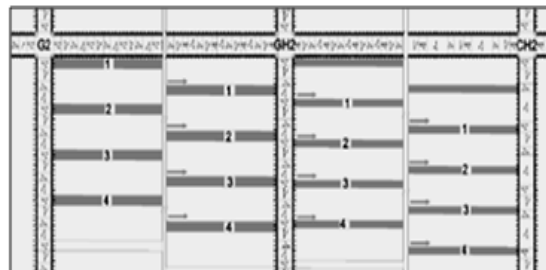


Figure: 3 Time Space Diagram for Travel time Calculation



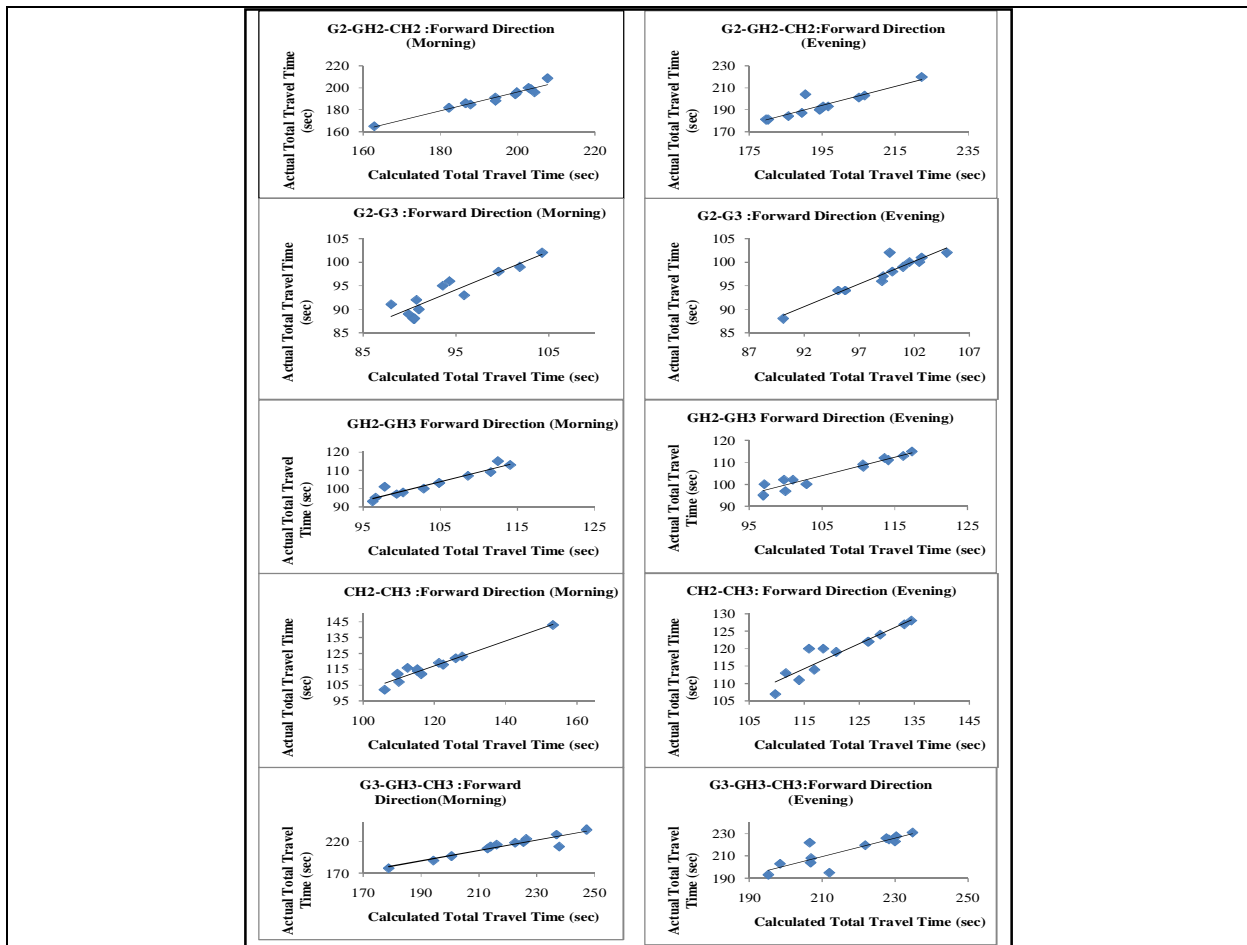


Figure 4: Forward & Backward Direction Linear Trend Analysis for all Junctions

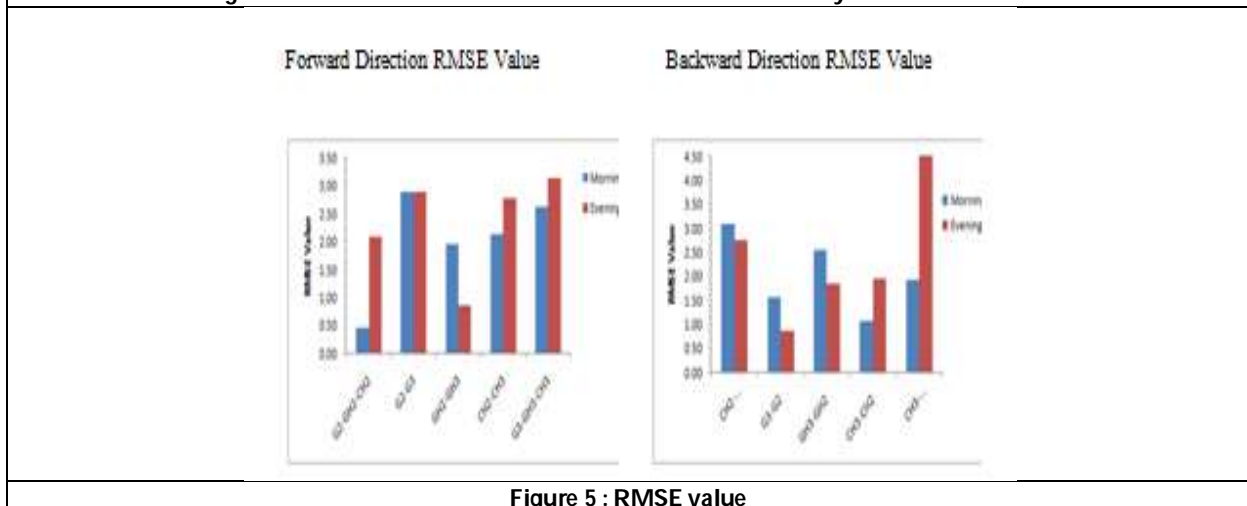


Figure 5 : RMSE value





A Study of the Relationship between Social Media use and Stress in Young Adults

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ABSTRACT

This study, titled as "A Study of the Relationship between Social Media Use and Stress in Young Adults," explored the link between social media usage and stress among young adults aged 20-35, along with potential gender differences. Using Pearson's correlation, a significant positive relationship ($r = 0.32$, $p < 0.01$) was found, indicating that higher social media use is associated with increased stress. The study also suggests a possible feedback loop, where stress leads to more social media use, further heightening stress levels. Independent t-tests showed no significant gender differences in stress across low, medium, and high social media usage categories ($p > 0.05$), though females consistently had slightly higher mean stress levels, consistent with previous research. Overall, the findings indicate that while social media use is linked to increased stress, this effect does not significantly differ between young adult males and females.

Keywords: social media use, stress, young adults, gender differences, Pearson's correlation, feedback loop.





INTRODUCTION

The widespread use of social media has become a defining feature of modern society, connecting people across the globe through platforms like Facebook, Twitter, and Instagram. While it offers numerous benefits, such as bridging distances and enabling real-time interactions, concerns about its potential negative effects, particularly its association with stress, have emerged. The constant connectivity and information overload of digital platforms can contribute to heightened stress levels, prompting discussions on individual well-being and mental health. To better understand this phenomenon, it is essential to define key terms related to the study. Social media refers to digital platforms for creating, sharing, and exchanging content (Kaplan & Haenlein, 2010), encompassing sites such as Facebook, Instagram, Twitter, LinkedIn, YouTube, and Pinterest. These platforms play a significant role in modern social interactions and have become integral to daily life. Now Stress is defined by Selye (1936) as "the non-specific response of the body to any demand for change," with common triggers including work, relationships, finances, and health. Chronic stress can lead to significant physical and mental health issues, making its management crucial. Effective strategies include mindfulness, exercise, and social support (Tan et al., 2018). Additionally, this study focuses on young adulthood, a developmental stage encompassing ages 20 to 35, characterized by maturity, new responsibilities, and personal growth (American Psychological Association, 2023). By examining how social media impacts stress within this demographic, the study considers potential gender differences in stress responses, contributing valuable insights into the broader dialogue surrounding mental health in the digital age. This research investigates the correlation between social media use and stress among young adults aged 20-35, examining whether this relationship differs between males and females. Given that young adults are particularly influenced by social media trends, understanding how these interactions affect stress is crucial. The study aims not to establish causality but to explore the nuanced connection between social media engagement and stress responses, considering possible gender differences. The findings could be valuable for researchers, practitioners, and policymakers, offering insights to develop interventions, guidelines, and balanced digital consumption strategies. By focusing on the unique challenges faced by young adults, this research adds to the ongoing dialogue about the effects of social media on mental health in the digital age.

A literature review on the relationship between social media use and stress among young adults has found mixed results, with some studies showing a positive relationship and others showing no significant relationship. A study published in the Journal of Social Science & Medicine in 2016 found that excessive use of social media is associated with increased stress among adults. (Lin et al., 2016) Another study published in the Journal of Adolescent Health in 2016 found that social media use was positively associated with stress among adolescents. (Hale et al., 2016) Another study published in the Journal of Adolescence in 2016 found that social media use was significantly associated with increased stress levels, suggesting that social media use may exacerbate existing stressors. (Woods et al., 2016) On the other hand, a study published in the International Journal of Environmental Research and Public Health in 2017 found that social media use did not significantly predict stress among adult social media users. (Alhabash et al., 2017) A meta-analysis published in the Journal of Behavioral Addictions in 2018 found that social media use was positively associated with stress among adults, but the relationship was small in magnitude. (Baumeister et al., 2018) A study published in the Journal of Affective Disorders in 2018 found that social media use did not significantly predict stress among college students. (Brossard et al., 2018) Additionally, meta-analysis published in the Journal of Behavioral Addictions in 2019 found that social media use was associated with increased stress, but the relationship was small in magnitude. (Kuppens et al., 2019) A study published in the Journal of Nursing Education in 2020 found that social media use was significantly associated with increased risk of depression, as well as with increased stress levels. (Lee et al., 2020) It's worth noting that, the relationship between social media use and stress can be bi-directional, meaning that stress can lead to increased social media use, as well as increased social media use leading to stress. Overall, research on the relationship between social media use and stress among adults is complex.



**Deepanshu and Shonali****Aim**

The aim of the study was to explore the relationship between Social Media Use and Stress in Young Adults and the potential gender differences.

Objectives**1.Relationship Between Social Media Use and Stress**

To examine the link between social media use and stress in young adults (aged 20-35). This will help identify associations and inform strategies for healthier social media habits and stress management.

2.Gender Differences in Social Media Use and Stress

To investigate gender differences in the social media-stress relationship among young adults (20-35), offering insights for developing gender-specific interventions.

Hypotheses

1. There is a significant relationship between social media use and stress among young adults (20-35).
2. There is a significant difference in the social media-stress relationship between young adult males and females (20-35).

Rationale of The Study

Social media platforms like Facebook, Twitter, and Instagram are central to modern life, yet their use may be linked to increased stress. Chronic stress poses risks to both physical and mental health, making it essential to identify contributing factors to develop effective interventions. Young adults, undergoing major life transitions and being heavy users of social media, are particularly vulnerable to stress. This study aims to investigate the correlation between social media use and stress in this group, examining potential gender differences. Understanding these differences can help in developing targeted strategies for healthier social media habits and stress management. The findings will contribute to existing knowledge by highlighting how social media impacts stress levels among young adults, with a focus on gender-specific experiences. This can guide future interventions, educational initiatives, and support strategies tailored to young adults' unique needs.

RESEARCH METHODOLOGY**Design**

This study employed a survey research design using a quantitative approach to assess the relationship between social media use and perceived stress among young adults. The data was collected through self-report questionnaires distributed online, ensuring accessibility and ease of participation.

Sample

The sample for the study consisted of 100 young adults, evenly divided between 50 males and 50 females, all residing in Shimla city. Participants were aged between 20 and 35 years and were recruited through online platforms by sharing a Google Forms link. Inclusion criteria required participants to fall within the specified age range, with no restrictions based on their level of social media use or stress. The sampling procedure ensured voluntary participation, allowing individuals from various occupational and educational backgrounds to join. This approach ensured a diverse representation of young adults while maintaining focus on the target population for the study.

Tools Used

The tools used were Perceived Stress Scale (PSS) and the social media usage section, which was converted into Google Form and distributed across various online platforms to recruit participants. The following is the description of the tools



**Deepanshu and Shonali****Perceived Stress Scale (PSS)**

The PSS, developed by Sheldon Cohen (1983), measures the extent to which individuals perceive situations in their lives as stressful. It consists of 10 items rated on a 5-point Likert scale ranging from 0 (Never) to 4 (Very Often), with higher scores indicating greater perceived stress. The scale has strong internal consistency, with Cronbach's alpha values ranging from 0.78 to 0.91, and good test-retest reliability, with correlation coefficients between 0.70 and 0.85. This standardized tool is widely used in both research and clinical contexts for measuring stress.

Social Media Usage Section

This section captured participants' average hours per day (AHPD) spent on key social media platforms, including Facebook, Instagram, Twitter, LinkedIn, YouTube, and Pinterest, with an option to mention additional platforms. The AHPD data were used to classify participants into low, medium, and high social media usage categories to analyze patterns in engagement.

The online format ensured accessibility and ease of participation, with participants able to respond anonymously. These tools provided data for both stress and social media data, which was essential for examining the relationship between the two variables and analyzing potential gender differences.

Procedure

The participants for the study were recruited online through various social media platforms using a Google Forms link, ensuring voluntary participation. Before proceeding, they were provided with a brief description of the study and gave informed consent. The data collection involved an online questionnaire, which gathered demographic details, responses to the Perceived Stress Scale (PSS), and information on the average hours per day (AHPD) spent on six primary social media platforms—Facebook, Instagram, Twitter, LinkedIn, YouTube, and Pinterest—along with any additional platforms specified by participants. Based on their AHPD, participants were categorized into low, medium, and high social media usage groups. Their perceived stress levels were assessed using the PSS, with higher scores reflecting greater stress. Pearson correlation was used to determine the relationship between social media use and stress, while independent t-tests analyzed gender differences in stress across usage categories, with significance levels set at 0.01 and 0.05, respectively. Ethical guidelines were followed throughout the process, ensuring participants' anonymity and confidentiality, with the option to withdraw at any point without penalty.

RESULT AND DISCUSSION

The aim of the study was to explore the relationship between Social Media Use and Stress in Young Adults, thus accordingly the objectives and hypotheses were formulated. To test our first hypothesis, i.e. 'There will be a significant relationship between the use of social media and stress among young adults aged between 20 and 35,' we calculated the Pearson's correlation coefficient (r). We examined the Average Hours per Day (AHPD) that young adults spent on social media and their reported stress levels. The correlation coefficient obtained was 0.32. Our first hypothesis was supported by the data, as the Pearson's correlation coefficient of 0.32 showed a statistically significant positive relationship between social media use and stress among young adults aged 20 to 35. As seen in Table 1 this finding suggests that, on average, as the amount of time young adults spend on social media increases, their reported stress levels also tend to increase. Importantly, the correlation, while statistically significant (t -stat = 3.42, p -value = 0.0009; $p < 0.01$), was relatively weak ($r = 0.32$). This indicates that while there is a discernible connection between social media usage and stress, other factors beyond social media likely contribute to stress levels as well. As part of our first objective, we sought to explore the relationship between social media use and stress among young adults aged between 20 and 35. Based on the analysis, our results demonstrate a statistically significant positive association between social media use and stress in this age group. This indicates that social media use might have an impact on the stress levels experienced by young adults within this age range. It's intriguing to consider an alternative perspective in light of these findings. As the data shows a positive correlation between social media usage and stress, it's plausible to suggest a reciprocal relationship as well. Individuals experiencing high levels of stress might turn to social media platforms as a means of coping, seeking distraction, or finding support. This interaction between stress



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and social media use could create a feedback loop, where heightened stress prompts more social media engagement, which in turn could contribute to further stress. To test our second hypothesis, i.e. "There will be significant difference between the relationship of use of social media and stress in young adult males as compared to young adult females aged between 20 and 35." We categorized the participants into three groups based on their social media usage: low usage (2 hours or below), medium usage (3 to 5 hours), and high usage (6 hours or above). We then conducted independent t-tests to assess the differences in stress levels between males and females within each usage category. The resultant figures can be seen in Table 2. For 2 hours or below usage (low usage): The results of the independent t-test revealed that young adult females had a slightly higher mean stress level (16.57) compared to young adult males (15.72) in the low usage category. However, the difference was not statistically significant, with a t-statistic of 0.45 and a p-value of 0.65, which exceeded the significance level of 0.05. Therefore, we do not have sufficient evidence to reject the null hypothesis. These findings suggest that although females showed slightly higher mean stress levels, the difference in stress levels between young adult males and females in the low usage category is not significant. For 3 to 5 hours of Usage (medium usage): Similarly, the independent t-test showed no statistically significant difference in stress levels between young adult males and females in the medium usage category. The mean stress level for females was 21.03, while it was 19.76 for males. The t-statistic was 0.67, and the p-value was 0.50, which is above the significance level. Therefore, we do not have enough evidence to reject the null hypothesis. These results indicate that although females displayed a slightly higher mean stress level, the difference in stress levels between young adult males and females in the medium usage category is not significant. For 6 hours or above usage (high usage): Similarly, the independent t-test demonstrated no statistically significant difference in stress levels between young adult males and females in the high usage category. The mean stress level for females was 24.66, while it was 21.42 for males. The t-statistic was 1.12, and the p-value was 0.29, which exceeds the significance level. Therefore, we do not have sufficient evidence to reject the null hypothesis. These findings suggest that although females exhibited a slightly higher mean stress level, the difference in stress levels between young adult males and females in the high usage category is not significant.

The second objective of this study was to investigate potential gender differences in the relationship between social media use and stress among young adults within different usage categories. Based on the results of the independent t-tests, we found no statistically significant differences in stress levels between young adult males and females in any of the three usage categories (low, medium, and high). Although females displayed slightly higher mean stress levels compared to males in each category (as seen in the Table 3) the differences were not significant. The consistently higher mean stress levels exhibited by females as compared to males in each usage category align with the historical researches that indicate that females often report higher levels of stress, possibly due to societal expectations, roles, and hormonal factors. (Kessler et al., 1985; Boyd et al., 2015). These findings indicate that, within each usage category, social media use does not appear to lead to significant gender differences in stress levels between young adult males and females aged between 20 and 35. In conclusion, our study did not find any significant gender differences in stress levels for young adults within different social media usage categories. This suggests that, irrespective of social media usage patterns, the impact on stress levels does not significantly vary between young adult males and females in the specified age group.

CONCLUSION

The study explored the relationship between social media use and stress among young adults aged 20-35, examining potential gender differences. Findings showed a statistically significant but weak positive correlation ($r = 0.32$, $p < 0.01$) between social media use and stress, suggesting that higher social media engagement is linked to increased stress. This may indicate a feedback loop where stress prompts more social media use, further elevating stress. Gender analysis across low, medium, and high social media usage categories found no significant differences ($p > 0.05$), implying that other factors may play a more significant role in stress disparities among young adults. Future research should explore additional variables like work-life balance and social support. The study highlights the need for mindful, balanced social media use to mitigate stress. While social media has benefits, excessive use may increase



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stress. Promoting healthy digital habits can support well-being, and ongoing research is crucial to understanding the broader impact of technology on mental health.

Delimitation

This study investigates the relationship between social media use and stress among young adults, focusing on males and females in Shimla city. The geographical scope is limited to Shimla, meaning findings may not be generalizable beyond this area. Results should be interpreted within this local context, with caution applied when extending them to other locations. The study sample consists of 100 participants, with an equal gender split (50 males, 50 females). This allows for focused analysis, but the limited sample size means findings may not reflect the broader young adult population. While recognizing these limitations, the study still provides insights into the link between social media use and stress, laying a foundation for future research and offering potential implications for similar groups in other regions.

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Conflict of Interest

The author declares no conflict of interest.

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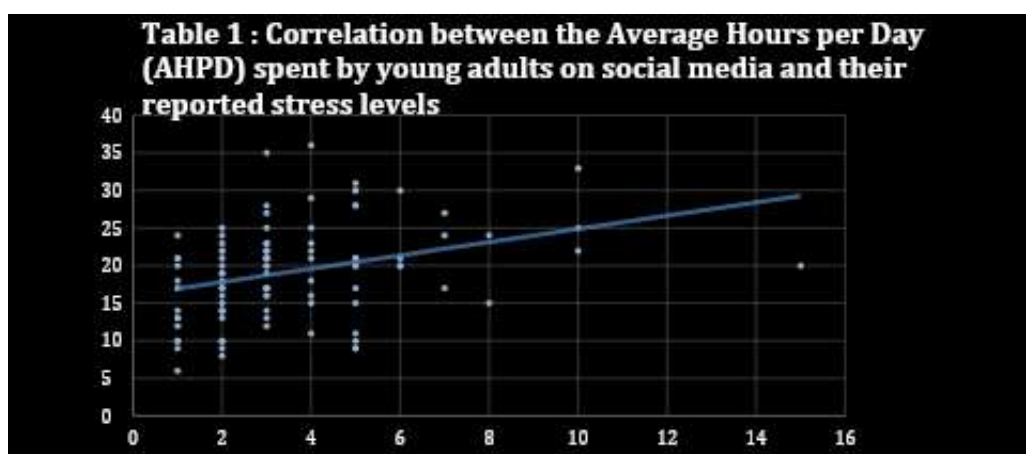
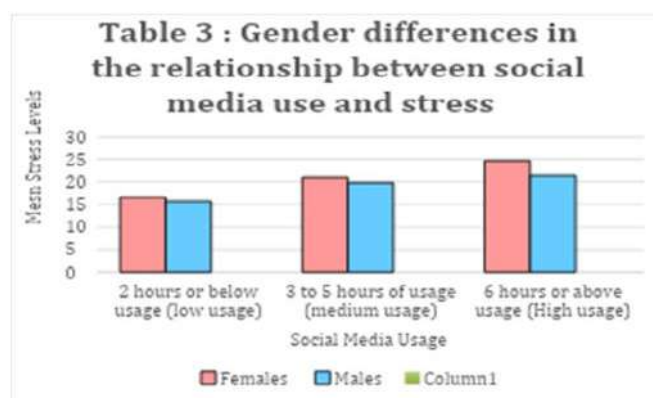


Table.2: 2 Hours or Below Usage (Low Usage) 3 To 5 Hours of Usage (Medium Usage) 6 Hours or Above Usage (High Usage)

Mean	Female	Male	Female	Male	Female	Male
SD	16.57	15.72	21.03	19.76	24.66	21.42
t Stat	5.80	4.82	5.87	7.04	6.28	3.45
t Critical two-tail	0.45	0.67	1.12			
P Value (T<=t) two-tail	2.06	2.02	2.30			
	0.35	0.50	0.29			





A Review on: The Deadly Disease in Pediatric Sporadic Caused by CHPV Encephalitis due to Temperature of Climate Variability

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ABSTRACT

The Chandipura virus disease is a mostly ignored but rapidly increasing exotic tropical disease in India. This review article addresses the present issue statement of this disease. The geographic distribution of patients with documented cases is detailed, as well as the epidemiology and clinical aspects. There have been stated disputes over it. Preventive measures, which constitute the cornerstone of management, have also been thoroughly examined. It has been stated how to prepare for disease and possible bioterrorism threats. In India, the Chandipura virus (CHPV) has been linked for more than ten years to the increased incidence of preventable deaths from acute encephalitis syndrome. Within the Rhabdoviridae family is CHPV. An effective CHPV preventative agent was assessed using a vaccine candidate based on Vero cells. To inhibit CHPV infection, prevention is the best strategy. Reducing the spread of CHPV in rural areas will require controlling disease-transmitting vectors, as well as promoting proper diet, hygiene, and awareness.

Keywords: Chandipura virus, pediatric sporadic encephalitis, Vectors, Sandflies, Epidemiology, classification of virus, India scenario





INTRODUCTION

The Two febrile cases in Nagpur, Maharashtra state, India, in 1965 led to the discovery of the Chandipura virus (CHPV), which caused an intense fever outbreak.[1,2,3] In 1966, Bhatt and Rodrigues identified the CHPV as a new agent that causes feverish sickness. The virus was given its name based on the location of its initial isolation in the Maharashtra region of Chandipura. [4] As a result, the release of the JE vaccine received a lot of attention. Even with the vaccination being widely available, more and more AES cases are coming out of India. [5] In India, the majority of premature deaths are caused by acute encephalitis syndrome, or AES. The Japanese encephalitis virus (JEV) infection or bacterial meningitis are thought to be the cause in the majority of cases. [6] Encephalitis pathology can be broadly classified into two basic categories: two types of encephalitis: immune-mediated and infection-related. [7] Infection-related encephalitis results directly from a virus entering the central nervous system, whereas auto-immune mediated encephalitis is associated with systemic infection or vaccination and is mediated by a pathologic immune response primarily directed against myelin, affecting the brain and spinal cord. Arbovirus-related illnesses are managed symptomatically because there isn't a specific cure.[8] While children under the age of 15 are more susceptible, all encephalitis symptoms, such as high-grade fever, vomiting, altered sensorium, generalized convulsions, decerebrate posture, and grade IV coma, are similar in adults. [9,10] Despite the fact that various theories have been put out, the patients' quick decline and eventual death have not been well explained.[11-13] Early experiments using the immunofluorescent antibody method to detect the presence of CHPV in brain biopsy tissues suggested a likely connection between CHPV.[14] But the role of CHPV and the precise mechanism of action could not be explained. [15] These incidents suggested that the deadly Chandipura virus may have spread throughout the Indian Subcontinent. [16]

Classification of Chandipura virus[17]

Etiology and epidemiology

It is carried by vectors such as sandflies, mosquitoes, and ticks. The case-fatality ratio of CHPV infection is significant (56-75%), and there is presently no vaccine or specific treatment available for the virus. Improved survival may result from early access to care and very supportive patient care. Authorities are working to stop the spread of CHPV, but given the favorable conditions the monsoon season is giving vector populations in the affected areas, further virus transmission could happen in the following weeks. The World Health Organization recommends vector control in addition to protecting against tick, mosquito, and sandfly bites in order to halt the spread of CHPV. The condition, which primarily affects youngsters under the age of 15, can start as a feverish sickness and develop to convulsions, a coma, and in rare circumstances, death. [18]

Virology

It is a member of the Rhabdoviridae family and genus Vesiculovirus. The single-stranded RNA genome of this virus is roughly 11 kilobases in size and possesses negative polarity. The nucleocapsid protein (N), phosphoprotein (P), matrix protein (M), glycoprotein (G), and large structural protein (L) are the five structural proteins that are encoded by the genome. They are generated as five monocistronic mRNAs. [19]

Life cycle of a virus

There are distinct phases in the vesiculo virus life cycle, which are as follows: [20]

Transmission and spreadability

Scientists at the National Institute of Virology, Pune, demonstrated in 1967 that mosquitoes are capable of vectoring CHPV. [21] *Phlebotomus papatasi* is a productive reservoir for the CHPV in laboratory settings, demonstrating proliferation, venereal, and transovarial transmission. [22, 23] The virus may persist in nature during non-epidemic times due to *P. papatasi*'s ability to spread the infection vertically and venereally. This process may have enabled the virus to withstand extended periods of dormancy and start epidemics when the number of sandflies rose in an environment that was conducive to doing so. A zoophilic species called *P. argentipus* has also been shown to be



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capable of horizontally spreading the virus to young mice.[24] A recent study examined the ability of the common mosquito in Southeast Asia and India, *Culex gelidus*, to transmit a variety of tropical viruses, including CHPV. Since *C. gelidus* has been shown to harbor more than 5 log₁₀TCID₅₀ of CHPV per milliliter, it has been suggested that it could be a possible CHPV vector. [25]

Indian scenario

Recently, there has been evidence of a clear correlation between CHPV and cases of pediatric sporadic encephalitis as well as several outbreaks in Andhra Pradesh (2004, 2005, 2007 and 2008), Gujarat (2005, 2009–12), and the Vidarbha region of Maharashtra (2007, 2009–12). NIV uses outbreak investigations, sero-surveys, and clinical specimen referrals to determine the prevalence and seasonal activity of the virus in these areas. In the Vidarbha region of Maharashtra, pools of sand flies gathered during outbreak investigations have yielded the isolation of CHPV recently. Since its discovery in India and the aforementioned CHPV activity, it was thought to be limited to that country alone.[1]

- Since early June 2024, at least 38 individuals have perished in India from the worst Chandipura virus outbreak in over 20 years, the most of them were youngsters and teenagers.[26]
- Since July 19, 2024, there has been a daily trend of fewer new instances of AES.[27]
- The Indian Ministry of Health and Family Welfare released a news release on July 20, 2024, detailing instances and fatalities related to the Chandipura virus (CHPV). Cases of Acute Encephalitis Syndrome (AES) in children under 15 years old have been reported in the state of Gujarat from early June 2024. 75 AES cases from 21 Gujarati districts and companies, 2 from Rajasthan, and 1 from Madhya Pradesh have been documented as of July 20, 2024. 28 cases have led to fatalities out of them. Nine samples out of the 76 that were examined at the NIV in Pune have the Chandipura Virus (CHPV) verified as positive. Gujarat is home to the five related deaths and all nine CHPV-positive cases.
- In Gujarat state, there were 101 AES instances overall on July 24, 2024, according to unreliable media reports, including 38 deaths. 4,160,000 homes with mud walls have been covered by the state-wide fumigation and cleanliness campaign. More than 62,000 households have had insecticides sprayed. [28]
- 53 Chandipura virus infections have been confirmed in India as of July 31, according to Union Health Minister J. P. Nadda, who informed the Rajya Sabha on Tuesday, August 6, 2024. Of these instances, 51 are from Gujarat and two are from Rajasthan.[29,30]
- On August 15, 2024, the Indian government's Ministry of Health and Family Welfare said that there had been 245 cases of AES, with 82 deaths (CFR 33%). There are now 43 districts in India where AES instances are being reported. Similar to earlier epidemics, cases are intermittently found in a number of areas. Notably, the state of Gujarat experiences an increase in CHPV epidemics every four to five years.
- It is spread by vectors like ticks, mosquitoes, and sandflies on August 23, 2024. CHPV infection has a high case-fatality ratio (56-75%), and there is currently no vaccination or targeted treatment for the virus. Early access to care and highly supportive patient care can improve survival. While efforts are being made by authorities to curb the spread of CHPV, additional viral transmission may occur in the upcoming weeks due to the favorable conditions that the monsoon season is providing for vector populations in the impacted areas. To stop the transmission of CHPV, the World Health Organization advises vector control as well as prevention against tick, mosquito, and sandfly bites.
- In 64 out of the 245 reported instances of AES, reverse transcription polymerase chain reaction (RT-PCR) or immunoglobulin M enzyme-linked immunosorbent test (IgM ELISA) have been employed to verify the presence of CHPV. Three instances have been reported from Rajasthan State, while 61 cases from Gujarat State are among the 64 verified cases.

Chandipura Virus: Precautions

In order to reduce mosquito numbers, authorities have sent out 50 teams for thorough dusting operations and have recommended that farmers apply pesticides and insecticides. To prevent mosquito bites, parents are advised to wear their kids in full-sleeved clothing. [31]





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Prevention and Control**When a CHPV outbreak is suspected, the following actions should be kept an eye on:**

1. Monitoring of youngsters who are affected by fever.
2. Intractable intra- and parodomestic activity.
3. The observation of insects
4. Morning vector collection, including resting mosquitoes indoors and sand flies
5. Recursive indoor spraying with 5% Alpha cypermethrin.
6. Employing an insecticide-treated mosquito net with a 2.5% deltamethrin flow.
7. Daily (or routine) observation of the impacted populace.
8. The fogging of pyrethrum

Thus, a number of guidelines are available to stop and manage Chandipura encephalitis, which is further divided into two categories: acute and chronic.

The Ministry of Health and Family Welfare have taken the following prevention and control measures:

1. **Deployment of National Joint Outbreak Response Team (NJORT):** The Gujarat state administration has received assistance from a professional team in carrying out comprehensive epidemiological studies and putting public health measures into action.
2. **Vector control measures:** Comprehensive fumigation and insecticidal spraying are being done to manage the virus's vectors, which include sandflies.
3. **Health and awareness campaigns:** There are programs in place to educate the general public and medical professionals about the virus, its symptoms, and how to avoid it.
4. **Research and monitoring:** The Gujarat Biotechnology Research Centre (GBRC) is closely monitoring the issue and conducting active research to find additional viruses that cause encephalitis.
5. **Advisories and coordination:** To assist adjacent states in reporting occurrences of AES, the National Centers for Disease Control (NCDC) and the National Center for Vector Borne Diseases Control (NCVBDC) are releasing joint warnings.

Laboratory Diagnosis

Simply based on a physical examination, CHPV cannot be diagnosed because the virus does not exhibit a distinct clinical picture. According to recommendations from the National Institute of Virus (NIV) in Pune, India, there are a few serological, molecular, and tissue culture-based techniques available for diagnosing instances of Chandipura viral encephalitis.

Approach of vaccine

After two doses, mice challenged with a live virus (100 PFU) showed effective protection against CHPV against the inactivated vaccine candidate based on vero cells. Following the third dosage, the antibody titer varied from 1:80 to 1:320. Mice challenged with live virus even through the intracranial route survived if they showed a neutralizing antibody titer greater than 1:20. Another method used a proposed vaccine that used an expression system for Baculovirus to recombine the CHPV Glycoprotein gene (G-gene). The vaccine protected 90% of the vaccinated mice against an intracerebral challenge with 100 LD50 of the homologous strain.[32]

CONCLUSION

This unique case of CHPV encephalitis has prompted the World Health Organization to declare a public health emergency of worldwide concern, which is thought to have originated from a member of the Rhabdoviridae virus family. The World Health Organization has classified the CHPV encephalitis outbreak as a "pandemic," posing a threat to India's public health, medical, and economic systems. Even with the implementation of appropriate and prompt containment and mitigation measures, new cases of CHPV encephalitis are being found every day in India. India has so far continued to handle this issue with a well-thought-out strategy. The Indian government's Ministry of



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Health and Family Welfare recorded 245 instances of AES between June and August 2024, with 82 fatalities (CFR 56-75%). There are now 43 districts in India where AES instances are being reported. Cases are sporadically present across various districts as in previous outbreaks.

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Author contribution

DB, NR, GA, GS and AJ conceptualized the review idea. DB, NR, GA, GS and AJ investigated, wrote, and reviewed the manuscript. DB and NR collected and validated the data. DB, GA, and GS, AJ contributed to the methodology. DB, AJ & NR wrote the original draft and provided resources. All authors are responsible for the scientific content and integrity of this manuscript.

Conflict of interests

No conflict of interests declared.

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Table: 1 Scenario of outbreaks from 1965 to till

Year of isolation	Place of isolation	% of Cases
1965	First detected and isolated virus in Nagpur, Maharashtra state, India	2%
1997 & 2002	Warangal district, Andhra Pradesh	5%
2003	11 districts, Andhra Pradesh	56%
2004	Gujarat State, India, CFR 78.3% among children, virus isolated	78.3%
2004-05	Anti-CHPV neutralizing antibodies (NAbs) in 65.3% sera CHPV was isolated	65.3%
2005-2006	Andhra Pradesh Surveillance within hospitals, about 54.4% CFR	54.4%
2007-2008	Sandflies from affected locations in Nagpur, Maharashtra, had viral RNA found in them (CDR 43.6%).	43.6%
2009	Research conducted in Andhra Pradesh on hospitalized cases of encephalitis revealed that 8	80%

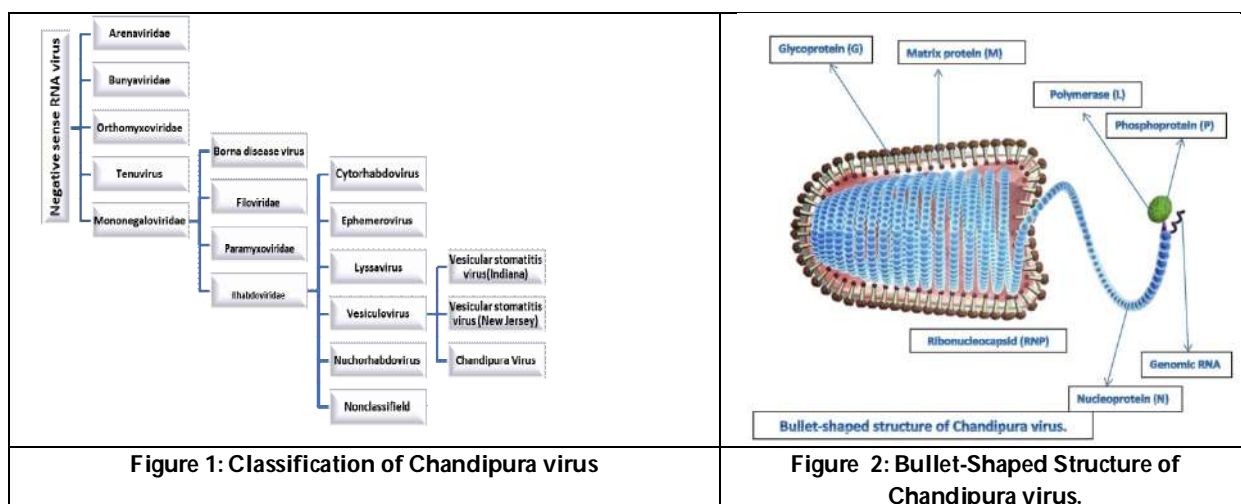


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	out of 10 cases had CHPV infection by RT-PCR, and only one out of the 132 contact sera obtained in Hyderabad region 1 had anti-CHPV IgM antibodies.	
2010-11	Anti-CHPV IgM antibodies were found in 10.56% [n=587] of the sera from fever cases in the Panchmahal area of Gujarat.	10.56%
2012	Anti-CHPV IgM ELISA and RT-PCR results for encephalitis cases from Maharashtra and Gujarat states showed 4.7% [n=130] confirmation.	4.7%
2024	The World Health Organization (WHO) called the current outbreak the largest in the past 20 years	55-75%

Table 2 Prevention & Control Short term and long term

S.No	Short Term	Long Term
1.	Timely and systematic monitoring of CHPV in villages at high risk, as well as timely and systematic anti-Chandipura activities both within and outside the home.	Determine which blocks, main health centers, village areas, and entire district are experiencing water logging that is conducive to mosquito reproduction. If necessary, import both larval and abate fish.
2.	Monitoring the fever cases in a cluster that are linked to vomiting, altered sensorium, and	Action against sand flies should be taken both before and after the monsoon, with 100% coverage.
3.	Review every week and provide input so that the block health officer can take appropriate measures.	Focal point spraying with insecticide (Alphacypermethrine 5%)
4.	Immediately report any flu-like symptoms.	Patients who test positive for Chandipura should receive second-line therapy.
5.	Wiping surfaces with viricidal solutions	The application of insecticide-treated mosquito nets (ITMN).



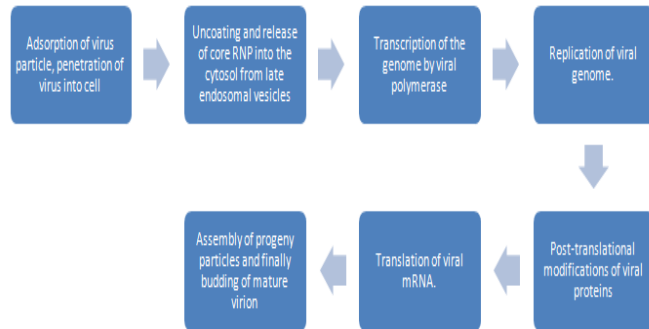


Figure 3:Life cycle of a virus

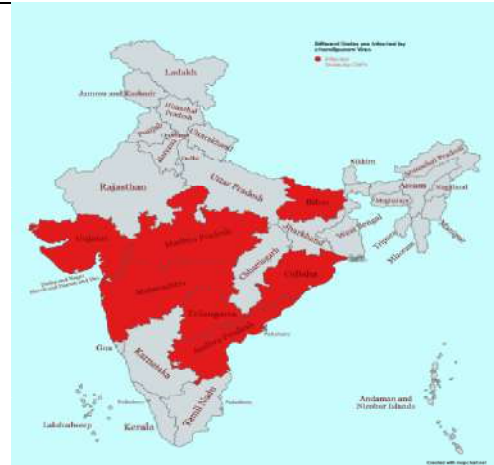


Figure 4: The figure shows the trends of outbreaks of CHPV infection across various states in India

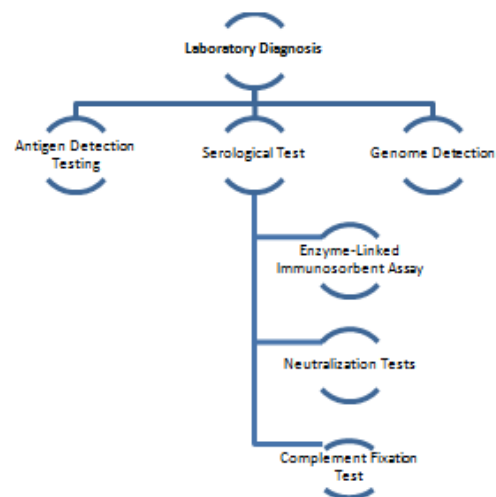


Figure 5: Flow chart of Laboratory Diagnosis Tests





Union Cordial Labeling of Tree Related Graphs

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ABSTRACT

In this present work, we investigated the existence of union cordial labeling of some tree related graphs.

Keywords: Cordial labeling, Intersection CL, Union Cordial labeling, labeling on trees, graph labeling.

INTRODUCTION

Let $X = \{1, 2, \dots, n\}$ be a set and let $\wp(X)$ be the power set of X which contains all the subsets of the set X . Graph Labeling [4] strongly relates Algebra and Structure of graphs and is generally used in communication networks. Throughout this work, we consider a graph $G = (V(G), E(G))$ to be a simple, finite, connected and undirected graph with p vertices and q edges [2] and [3]. Meena and Nagarajan [5] introduced the concept of intersection cordial labeling and proved that path, cycle, star, dragon, complete bipartite graphs and wheel related graphs [6] admit





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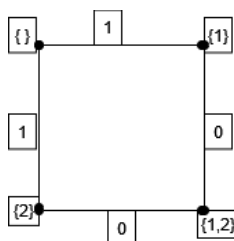
intersection cordial labeling. Following this, they discussed the intersection cordiality[7] of the graphs $2^k P_{2^n}$, $2^k C_{2^n}$, $2^k K_{1,2^n-1}$ and $2^k K_{2,2^n-2}$. Motivated from this topic, we introduced here a labeling using the power sets of X and discussed the existence of such labeling on some tree related graphs such as path, y-trees, combs, twigs, stars, bistars, double stars, coconut trees [5].

Definition

Let $f: V \rightarrow \wp(X)$ be an injection. Also let $2^{n-1} < p < 2^n$. Then the induced edge function $f^*: E(G) \rightarrow \{0,1\}$ defined by $f^*(uv) = \begin{cases} 1 & \text{if } |f(u) \cup f(v)| \text{ is odd} \\ 0 & \text{if } |f(u) \cup f(v)| \text{ is even} \end{cases}$. f^* is called a union cordial labeling if $|e_f(0) - e_f(1)|$ is either 0 or 1. A graph which admits union cordial labeling is said to be a union cordial graph.

Examples

Consider the graph with vertices labeled by $\emptyset, \{1\}, \{2\}, \{1,2\}$

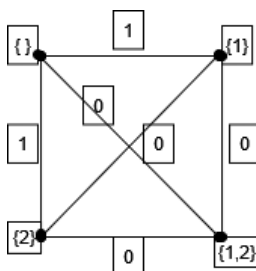


Here $e_f(0) = 2$ and $e_f(1) = 2$.

Hence $|e_f(0) - e_f(1)| = 2 - 2 = 0$

Therefore the given graph is an union cordial graph.

Consider the following graph:



Here $e_f(0) = 4$ and $e_f(1) = 2$. Hence $|e_f(0) - e_f(1)| = 4 - 2 = 2$

Therefore, the given graph is not union cordial.

Main Theorems

With the effect of example 2, we proved that complete graphs are not union cordial graphs.

Theorem: 2.1

Complete graphs, K_{2^n} , $n \geq 2$ are not union cordial graphs.

Proof:

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

Let $V(G) = \{u_1, u_2, \dots, u_{2^n}\}$ be the vertices of K_{2^n} , $n \geq 2$.

Label the vertices u_1, u_2, \dots, u_{2^n} with all the subsets of $\wp(X)$. Then





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for $n = 2$ (i.e.,) K_{2^2} , we get $|e_f(0) - e_f(1)| = 2^1$
 for $n = 3$ (i.e.,) K_{2^3} , we get $|e_f(0) - e_f(1)| = 2^2$
 for $n = 4$ (i.e.,) K_{2^4} , we get $|e_f(0) - e_f(1)| = 2^3$
 for $n = 5$ (i.e.,) K_{2^5} , we get $|e_f(0) - e_f(1)| = 2^4 \dots$ and so on.
 Continuing this process, $|e_f(0) - e_f(1)|$ never equals either 0 or 1, for any $n \geq 2$.
 Therefore, $K_{2^n}, n \geq 2$ are not union cordial graphs.

Path Related Graphs

Theorem:2.1.1

Paths, P_n admit union cordial labeling.

Proof

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

Let u_1, u_2, \dots, u_n be the vertices of P_n .

Let the vertices be labeled as follows:

u_1 by $\{1\}$; u_2 by $\{2\}$; u_3 by the element before X in $\wp(X)$;

u_4, u_5, \dots, u_{n-2} by the subsets next to $\{2\}$ in $\wp(X)$; u_{n-1} by \emptyset set and u_n by X .

Then by the definition of union cordial labeling, we get the labeling of edges as 0 or 1 and hence $|e_f(0) - e_f(1)|$ is either 0 or 1. Therefore, Paths admit union cordial labeling.

Theorem: 2.1.2

Y- trees, Y_k [1] are union cordial graphs.

Proof:

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

Let Y- tree, Y_k be a graph with k vertices $u_1, u_2, \dots, u_{k-2}, u_{k-1}, u_k$ and edge set as $\{u_1u_2, \{u_2u_3, \dots, \{u_{k-2}u_{k-1}\} \cup \{u_{k-2}u_{k-1}\}, \{u_{k-2}u_k\}\}$ satisfying $k = 2^n$.

Here u_{k-1} and u_k are pendant vertices adjacent to u_{k-2} .

First label the pendant vertices u_{k-1} and u_k by the \emptyset set and X . Then label u_1 by $\{1\}$; u_2 by $\{2\}$; u_3 by the subset before X in $\wp(X)$ as the labeling in paths; Moreover, label the remaining vertices $u_4, u_5, u_6, \dots, u_{k-2}$ by the remaining subsets of $\wp(X)$, in order. Thus the edge labeling provides $|e_f(0) - e_f(1)|$ as either 0 or 1.

Hence Y_k are union cordial graphs.

Theorem: 2.1.3

Comb graphs, $P_n \odot K_1$ admit union cordial labeling.

Proof

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

Let u_1, u_2, \dots, u_n be the vertices of the path P_n and v_1, v_2, \dots, v_n be the pendant vertices adjacent to u_1, u_2, \dots, u_n respectively. First label the pendant vertex v_1 by X and u_n , the end vertex of the path by \emptyset set. Then label the vertex sequence $u_1, v_2, u_2, v_3, u_3, \dots, v_{n-1}, u_{n-1}, v_n$ starting from the one element subset $\{1\}, \{2\}, \{3\}, \dots$ of $\wp(X)$, in order. Then by the definition of union cordial labeling, we get $|e_f(0) - e_f(1)| = 1$. Therefore, comb graphs admit union cordial labeling.

Theorem: 2.1.4

Twig graphs, T_k are union cordial graphs.

Proof

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.





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Let u_1, u_2, \dots, u_n be the vertices of the path; v_1, v_2, \dots, v_{n-2} be the pendant vertices attached below the internal vertices of the path and w_1, w_2, \dots, w_{n-2} be the pendant vertices attached above the internal vertices of the path. First label the vertex u_1 by X and u_n by \emptyset set. Then label the vertex sequence $u_2, v_1, w_1, u_3, v_2, w_2, \dots, u_{k-1}, v_{k-2}, w_{k-2}$ starting from the one element subset $\{1\}, \{2\}, \{3\}, \dots$ of $\wp(X)$, in order. Then by the definition of union cordial labeling, we get $|e_f(0) - e_f(1)| = 1$. Therefore, twig graphs are union cordial graphs.

Theorem: 2.1.5

Coconut tree, $CT(m, n)$ admits union cordial labeling.

Proof

Let $X = \{1, 2, \dots, k\}$ and $|\wp(X)| = 2^k$.

Let $V(G) = \{v_1, v_2, \dots, v_m, u_1, u_2, \dots, u_n\}$ be the vertices of $CT(m, n)$.

It has $m + n = 2^k$ vertices and $m + n - 1$ edges. Let v_m be the vertex in the path P_m where the 'n' pendant edges are appended. Let the vertex v_m be labeled by the \emptyset set. Label the remaining vertices (i.e., v_1, v_2, \dots, v_{m-1} in the path and the pendant vertices u_1, u_2, \dots, u_n by the subsets $\{1\}, \{2\}, \{3\}, \dots$ of $\wp(X)$. Then by the definition of union cordial labeling, we get the labeling of edges as 0 or 1 and hence $|e_f(0) - e_f(1)|$ is either 0 or 1. For $m \geq 5$, if the required result is not attained, then the labeling of vertices in the path can be altered as in labeling of paths (**By theorem:2.1.1**) which provides the required result. Therefore, Coconut tree admits union cordial labeling.

Star Related Graphs

Theorem: 2.2.1

Star graphs, $K_{1,q}$ are union cordial graphs.

Proof

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

Here $p = 2^n$ and $V(G) = \{v_1, v_2, \dots, v_p\}$.

Let v_p be the central vertex and v_1, v_2, \dots, v_{p-1} be the end vertices of the star $K_{1,q}$. Then $K_{1,q}$ contains $q = 2^n - 1$ edges. First label the central vertex by \emptyset set and then label the remaining vertices by the other subsets of $\wp(X)$. It is observed that the union of each subset labeled in the end vertices with \emptyset set contributes 2^{n-1} '1's to $e_f(1)$ and $2^{n-1} - 1$ '0's to $e_f(0)$. Now we get, $|e_f(0) - e_f(1)|$ is either 0 or 1. Therefore, star graphs are union cordial graphs.

Theorem: 2.2.3

Bistar graphs, $B_{m,m}$ admit union cordial labeling.

Proof

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

The graph $B_{m,m}$ has $2m + 2$ vertices and $2m + 1$ edges.

Let xy be the edge joining the two stars $K_{1,m}$ and $K_{1,m}$.

Let u_1, u_2, \dots, u_m be the vertices adjacent to x and $u_{m+1}, u_{m+2}, \dots, u_{2m}$ be the vertices adjacent to y .

Labeling

Let $|X| = \text{even}$. First label the vertices x and y by \emptyset set and X . Next label the vertices u_1, u_2, \dots, u_m , that are adjacent to x , by the subsets whose union with \emptyset set provides odd cardinality so that it contributes 'm' 1's to $e_f(1)$. Then label the vertices $u_{m+1}, u_{m+2}, \dots, u_{2m}$, that are adjacent to y , by the remaining subsets in $\wp(X)$ whose union with X yields X so that it contributes 'm' 0's to $e_f(0)$. Also, the edge xy (i.e., $\emptyset \cup X = X$ which again contributes one 0's to $e_f(0)$. Therefore, there are 'm + 1' 0's which finally results in $|e_f(0) - e_f(1)| = 1$ providing $B_{m,m}$, a union cordial graph.

Let $|X| = \text{odd}$. As in the previous case, label the vertices x and y by \emptyset set and X . Next label the vertices u_1, u_2, \dots, u_m , that are adjacent to x , by the subsets whose union with \emptyset set provides even cardinality so that it contributes 'm' 0's to





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$e_f(0)$. Then label the vertices $u_{m+1}, u_{m+2}, \dots, u_{2m}$, that are adjacent to y , by the remaining subsets in $\wp(X)$ whose union with X yields X so that it contributes 'm' 1's to $e_f(1)$. Moreover, the edge xy (i.e.) $\emptyset \cup X = X$ which again contributes one 1's to $e_f(1)$. Therefore, there are 'm + 1' 1's which finally results in $|e_f(0) - e_f(1)| = 1$ providing $B_{m,m}$, a union cordial graph.

Theorem: 2.2.3

Double star graphs, $D_{m,n}$, $m < n$ satisfying $m + n + 2 = 2^n$, are union cordial graphs.

Proof:

Let $X = \{1, 2, \dots, n\}$ and $|\wp(X)| = 2^n$.

Let $D_{m,n}$, $m < n$ be the double star graph satisfying $m + n + 2 = 2^n$. It has $m + n + 2$ vertices and $m + n + 1$ edges. Let xy be the edge joining the two stars $K_{1,m}$ and $K_{1,n}$. Also u_1, u_2, \dots, u_m be the vertices adjacent to x and v_1, v_2, \dots, v_n be the vertices adjacent to y . Now label the vertices $v_1, v_2, \dots, v_n, y, x, u_m, u_{m-1}, \dots, u_3$ starting from the one element subset, say $\{1\}$, of $\wp(X)$ and label the vertices u_2 and u_1 by the \emptyset set and X . Then there are either $\frac{m+n+2}{2}$ 1's and $\frac{m+n+2}{2} - 1$ 0's (or) $\frac{m+n+2}{2}$ 0's and $\frac{m+n+2}{2} - 1$ 1's providing $|e_f(0) - e_f(1)|$ is either 0 or 1. Hence $D_{m,n}$, $m < n$ are union cordial graphs.

CONCLUSION

In this work, we proved the existence of union cordial labeling of tree related graphs. Further, we will try to prove the same for some special classes of graphs.

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Assessing Depression and Gastro-Intestinal Problems in Post Bariatric Surgery Subjects Post 1-Month of Surgery

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ABSTRACT

Bariatric surgery is an indication for obese individuals who find it difficult to lose weight even after trying for years for weight loss with different strategies. It promises sustainable weight loss but also it comes with its complications. The present study is a prospective cohort study to record effect of bariatric surgery on mental health and gut issues post 1-month of surgery. The study aims to identify and address two main factors involved for subjects undergoing bariatric surgery 1) Whether or not mental health problems arise/worsen in post bariatric subjects and 2) Whether or not gut issues get resolved post bariatric surgery in obese individuals. 120 subjects were included for the study, undergoing bariatric surgery were observed for depression and gut problems pre- and post-1month surgery. GSRS scale and beck's depression inventory were used to assess gut issues and depression respectively. Result show significant decrease in the GSRS score ($p < 0.001$) while increase in the BDI-II ($p < 0.001$) score contributing to reduce quality of life pre- and post-surgery. The subjects should be well educated about post-surgery phase; a multidisciplinary approach should be provided for the bariatric surgery candidates to address mental health and gut related issues.

Keywords: Depression, bariatric surgery, metabolic surgery, gastro-intestinal problems, obesity.





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INTRODUCTION

Obesity is one of the morbid risk factors. Obese and overweight individuals are at higher risk of suffering from other morbid diseases such as hypertension, diabetes mellitus, hypothyroidism and many other metabolic/non-metabolic illnesses[1]. Gastro-intestinal problems are the commonest amongst obese individuals. The symptoms experienced by obese individual are similar to those experienced by individuals with gut issues such as, diarrhea, constipation, irregular bowel movements, sudden urge to defecate, regurgitation, acid reflux, irregular stool consistency, belching and borborygmus[2]. These problems are faced due to excess adiposity in abdominal region[3,4]. Also, it hampers with normal physiology of the body, dysregulates homeostasis and causes inconsistency in sympathetic and parasympathetic activity[5]. The constant inflammation in the gastro-intestinal tract further makes it difficult for an individual to return to normal homeostasis[6]. When these gastric problems interfere with an individual's routine life it further affects QOL and mental well-being, when individual seeks for permanent solution to these problems, bariatric surgery comes up as well-planned, logical alternative[7]. Bariatric surgery is so far best alternative for individuals who are tired with non-sustainable weight loss options. As the surgery promises to reverse all or most of the problems faced by the obese individual, it really does provide improvement in morbid diseases such as hypertension and diabetes mellitus[8]. Although, weight recidivism is another problem faced by post-bariatric surgery individuals, it does provide relief in morbid diseases for as short span as 3 years and in long-term for 15 years[8,9]. Post bariatric surgery results vary from individual to individual but majorly all the candidates of surgery experiences near identical symptoms in post-surgical phase. Obese individuals not only encounter with physical and physiological problems but they also face mental health problems, in the form of body image issues, eating disorders, depression, anxiety and suicidal tendencies[10,11]. Wide-range of mental health problems are prevalent in obese individuals, some of which are also result of poor gut health[10]. Post bariatric surgery these problems may or may not get addressed[12,13]. Thus, this study sought to address mental health of the obese individual undergone bariatric surgery. The post-surgical period is an important phase as it decides the success rate of bariatric surgery. The mental stability and physical ability are important parts of this phase. Thus, study is conducted post- 1 month of the surgery and comparison is made with pre-operative state of the individual.

MATERIALS AND METHODOLOGY

In this prospective observational study, cohort of 120 subjects were included for the study. The sample size was calculated from historic data in SPSS 22.0. The calculated sample size was 110 for 95% CI and power of the study kept at 80%. The data was obtained from single study center Hope obesity and multispecialty hospital located in Ahmedabad, Gujarat for 6 months. Inclusion criteria were both gender individuals under going bariatric surgery in age group of 18-60 years having BMI ≥ 30 and willing to participate. Exclusion criteria were limited but individuals with severe psychological disorders such as drug abuse, attempted suicide, self-induced vomiting (untreated eating disorder), past history of any neurological illness and comprehension disability were excluded. Informed consent was taken from all participants and their care-givers.

Main Outcome variables

Beck's depression inventory (BDI-II)

Beck's depression inventory is self-report questionnaire widely used in different clinical/hospital settings. It has 21 items and ranked on scale of 0-3 for severity, with minimum score 0 and maximum score 63. It takes 5-10 minutes to complete. In those diagnosed with depression, scores of 0-13 indicates minimal depression, 14-19 indicates mild depression, 20-28 indicates moderate depression and 29-63 indicates severe depression. Content validity of the BDI-II has improved following item replacements and rewording to reflect DSM-IV criteria for major depressive disorders. Mean correlation coefficients of 0.72 and 0.60 have been found between clinical ratings of depression and the BDI for psychiatric and non-psychiatric populations. Construct validity is high for the medical symptoms measured by the questionnaire, $\alpha = 0.92$ for psychiatric outpatients and 0.93 for college students. High concurrent validities have been



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demonstrated between the questionnaire and other measures of depression such as the Minnesota Multiphasic Personality Inventory-D, $r = 0.77(14)$. Criterion validity of the BDI-II is positively correlated with the Hamilton Depression Rating Scale ($r = 0.71$) with a high 1week test-retest reliability $r = 0.93$ (suggestion robustness against daily variations in mood) and an internal consistency of $\alpha = 91[14]$

Gastro-intestinal symptom rating scale (GSRS)

GSRS is a validated questionnaire consisting of 15 gastrointestinal symptom items, scored on a 7-point Likert scale (1= no discomfort and 7= severe discomfort) combined into the following clusters: abdominal pain, reflux, diarrhoea, constipation, and indigestion[15]. A cluster score was calculated only when all items in the cluster were answered. The means of the total score and of the scores for each symptom cluster are presented. GSRS has also been used in previous studies of bariatric surgery. The GSRS has good reliability and construct validity and the GSRS scales discriminate by GERD symptom severity and are responsive to treatment. The GSRS is a useful patient-rated symptom scale for evaluating the outcomes of treatment for GERD. The internal consistency reliabilities for the GSRS scales ranged from 0.61 to 0.83 and the intraclass correlation coefficients ranged from 0.42 to 0.60[16].

Procedure

The subjects were given questionnaires along with personal detail form at the time of their first visit to the hospital. The participants were assessed at the baseline pre-surgery when they had visited the hospital for first consultation, data of all the individuals who visited the hospital were recorded that is of individuals. Data of operated subjects was separated from the data of subjects who had decided to withdraw or didn't underwent surgery. Post-surgery 1-month during the subject's follow up period they were assessed again for BDI-II and GSRS. All the participants were informed about the questionnaires and assistance was provided wherever required. BDI-II does have translated versions but GSRS is available in English language only. The participants were explained in their native language about the scale when they were bewildered. The symptoms recorded on scale were verified with the care giver, especially when dealt with individuals with lower literacy rate or individuals from rural areas.

RESULTS AND DISCUSSION

In this observational study, statistical analysis was done to compare pre and post outcomes of BDI-II and GSRS. The statistical package SPSS 22.0 was used to analyze the data. The Kolmogorov-Smirnov (KS) test was used to test normality of the data. Paired t-test was used to conduct within group analysis amongst cohort participants and compare them at two different instances which is prior to surgery and post-surgically. Significant difference was considered when $p < 0.05$. The data are presented as mean (SD). Baseline characteristics of participants shown in table 1 and results of the study in table 2. Participants included in the study completed both pre and post operative assessment. No subjects were lost in follow up for the study as candidates had never missed post-op follow up appointment arranged for routine check-up. 61% participants were female. 25% of study population had studied up to high school and rest were graduated and did pursue higher education. Data of only individuals who had undergone bariatric surgery were analyzed. Details of data sample is as given in flowchart (fig 1). In present study participants, average weight loss experienced by all the individuals is 4-6 kgs in first month depending on two most important factors, 1) the surgery performed - bypass (more weight loss as compared to other option) or sleeve-gastrectomy and 2) obesity grading on an individual with inverse proportional relation between obesity grade and weight loss post-surgery. The result of t test for BDI-II showed significant difference ($p \text{ value} < 0.001$) for pre- and post-surgery measurements. Pre-surgery the mean (SD) score was 21.27 ± 10.61 and post-surgery it increased by 2 points in overall score that is 23.16 ± 9.61 as shown in table 2. For GSRS, it decreased from mean (SD) 6.64 ± 0.45 to mean (SD) score of 5.70 ± 0.54 showing significant ($p \text{ value} < 0.001$) reduction in overall scoring as shown in table 2. Further analysis of subsets of GSRS is shown in table 3. Present study was conducted to know quality of life of subjects undergoing bariatric surgery post 1-month of the surgery. The study results showed decrease score in GSRS post surgically while increased score on BDI-II scale suggesting subject's gastric discomforts related to obesity are decreased after minimum weight loss post 1-month. While subjects had increased score on depression inventory.



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Although the GSRS score is reduced but detailed analysis of it as shown in table 3, reveals changes in symptoms of regurgitation which is a common symptom after bariatric[17]. Complaints of diarrhea, constipation, flatulence decreases while on the other hand complaints of regurgitation, nausea and heart burn increases which lies in a subset of scale which has lesser score; thus, it justifies decreased GSRS score[18]. The subjects were knowing very little about post-surgical symptoms of gastro-intestinal tract, which left them mentally unprepared for following regurgitation and nausea. The unavailability of the GSRS in native language has played role in creating a bias. The symptoms described in the scale and as understood and explained by the hospital assistant to the subjects may not be accurate. The literacy rate of study participants has also played a role in creating bias for GSRS score. BDI-II scale has questions about excess recent weight loss. This question is for a depressed individual as depression leads to eating disorders suggesting changes in weight of an individual but in the present scenario, the significant weight loss is caused by bariatric surgery which leads to increase in severity score. Also, another reason for increased score on this inventory is for questions about fluctuating moods, sex life and overall feel-good factor which are affected because of surgery[19]. The subject's physiological system is still adapting the new change brought about by surgery.

The increased hunger sensation and reduction in appetite in some individuals, but unable to eat or sudden reduction in hunger as well as appetite in others puts the subjects in frustrated moods. The restrictive surgery has decreased the size of the stomach and the food volume which it can accommodate, which leads to symptoms of regurgitation and nausea[20]. Also, the overall well-being of the individuals gets disturbed leading to thoughts pertaining to life expectancy, death-related thoughts, thoughts about surgery going unsuccessful and thoughts regarding whether they are losing any weight after surgery or not[21,22]. This leads to negative performance in BDI-II. Prevalence of depression in obesity is a well-established fact and bariatric surgery may worsen depression score in such individuals, special keen attention should be given to individuals falling in moderate depression score range as they are at higher risk for developing severe depression post-surgery. At the end of study when subjects were asked to share their experience post-1 month of the surgery, it was almost similar with all of them. All the subjects receiving counselling pre-surgery were only partially aware about what to expect post-surgery and furthermore they were more excited about long-term effect of surgery rather than seeking information on post-immediate surgery effects, which justifies their lack of curiosity to know about short term outcomes of the surgery. However, the participants may or may not be curious about surgery outcomes but it is the duty of associated medical team to invest time in patient education. Other scales/questionnaire to assess mental health comprehensively such PSS for perceived anxiety and DASS – depression anxiety stress scale could have been better indicator of mental health for current study subjects, providing more precise results. Individuals undergoing bariatric surgery should be educated with present information and also the concerned rehab team should have this knowledge and treat patients accordingly for atleast first month of surgery.

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Table 1 Baseline characteristics of participants

Baseline characteristics	Number of participants (n=120)
Mean age of participants	43±12
Gender: Male	46
Female	74
Metabolic disorders: Diabetes	58
Hypertension	45
Thyroid	15
Ongoing mild psychiatric illness	2
Existing GERD on medication	3
Smokers/tobacco	28
Education qualification: 10 th pass	6
12 th pass	24
Graduate	52
Double graduate	38

Table 2 showing t test result for pre- and post-surgery

	Pre – surgery (Mean ± SD)	Post – 1month (Mean ± SD)	p value
BDI-II	21.27 ± 10.61	23.16 ± 9.61	<0.001
GSRS	6.64 ± 0.45	5.70 ± 0.54	<0.001

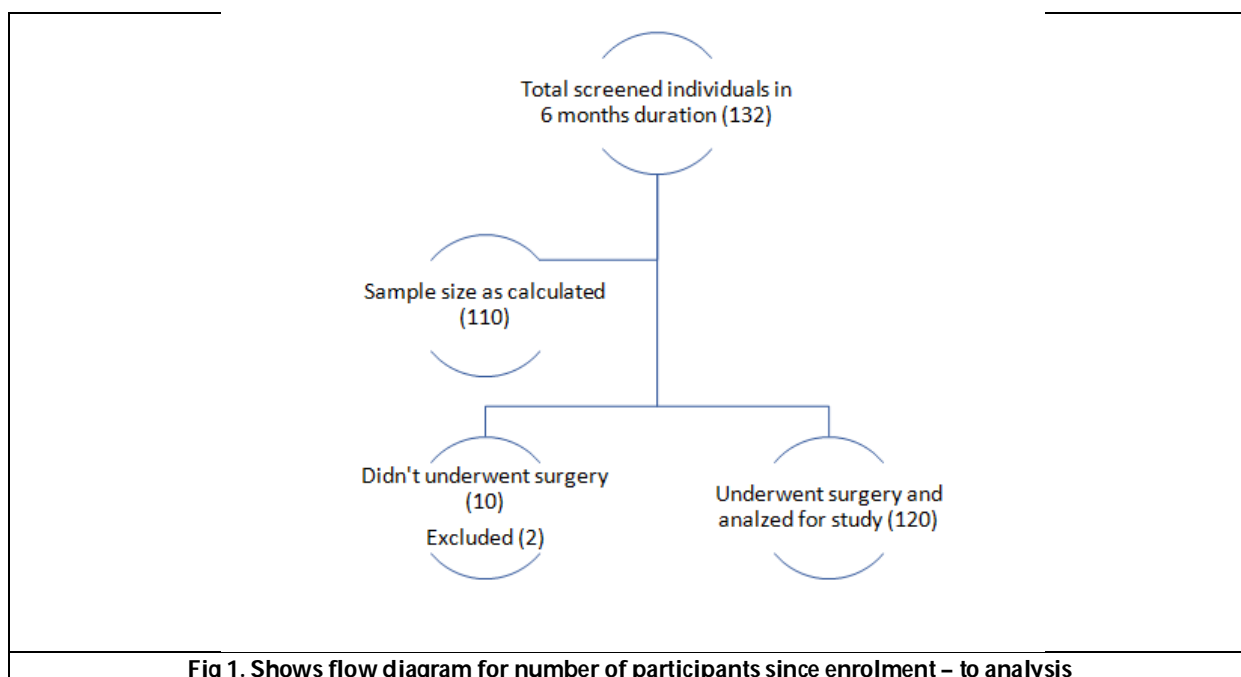
Table 3 showing detailed analysis of GSRS subsets

GSRS – subsets	Pre-surgery (total = 7.09)	Post-surgery (total = 6.1)
Abdominal pain	1	1.5
Reflux	1.5	1.6
Diarrhoea	1.6	1
Constipation	3	1
Indigestion	1.5	1





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Optimizing Aspect - based Sentiment Analysis for Code-Mixed Gujarati Texts : Methodological Innovations and Practical Applications

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ABSTRACT

Aspect-Based Sentiment Analysis (ABSA) is essential for extracting detailed opinions in texts, especially when dealing with code-mixed languages like Gujarati and English. This paper presents an optimized ABSA framework for code-mixed Gujarati texts, addressing the complexities of language switching. We introduce novel preprocessing techniques, including advanced language detection and normalization methods, to manage mixed-language components effectively. Using machine learning and deep learning models, our approach enhances sentiment detection accuracy in the presence of code-switching. Experimental results show significant improvements over traditional methods. Practical applications include better social media analysis and more accurate customer feedback interpretation. Our research offers robust solutions for ABSA in code-mixed texts, providing valuable tools for industries relying on precise sentiment analysis.

Keywords: Aspect-Based Sentiment Analysis, ABSA, Code-Mixed Texts, Gujarati-English, Sentiment Analysis, Language Detection, Machine Learning, Deep Learning, Social Media Analysis, Customer Feedback.





INTRODUCTION

Aspect-Based Sentiment Analysis (ABSA) has emerged as one of the critical approaches in natural language processing that helps in understanding opinions at the level of aspects by annotating sentiments concerning them. ABSA is different from the conventional sentiment analysis where the general view of the text is analyzed, while the particularities regarding the aspects are searched. This can be quite useful in areas where one is exploring detailed views and opinions that people hold on specific aspects about a product or a service that is being offered[1]. However, the operation of ABSA becomes challenging especially when working with code-mixed texts that are half in one language and the other half in another language. Inter language is a frequently observed strategy of bilinguals and multi linguals who switch between different languages during their discourse. This presents itself as a problem with natural language processing since these systems are typically developed to work with monolingual texts. For example, there are many texts in Indian languages with sometimes English mixed with the regional language; say for example Gujarati; this makes the general analysis of the sentiments more complex. Hence, the analysis of code-mixed Gujarati is evident in the communication that happens on social media, forums, and messaging apps – where millions of Gujarati speakers in India and across the world are part of. For interpreting the sentiments of such code-mixed texts that contain both Gujarati and English, it may not be very easy to process such a text. Generally, the historically used methodologies of sentiment analysis primarily based on monolingual datasets, fail to provide correct sentiment analysis in case of code-mixed language due to the distinction in the mode of expression[2]. In this paper the primary concern is to achieve the best result for ABSA pertaining to Code mixed Gujarati text leaving behind the linguistic and technical issues that occur while analyzing such a text. Specifically, our study's goal is to establish a reliable approach to be implemented in the model thereby addressing the issue of code-switching, which allows for the precise identification of sentiment in the context of mixed language. To this end, we put forward multiple methodological developments, namely, improved preprocessing, refined ABSA architecture, and machine learning and deep learning techniques[3].

Data Collection and Preprocessing

To start with, we gather a large number of real-world code-mixed Gujarati texts taken from social media platforms, forums, customer reviews, etc. In preparation of these texts, several processes are performed such as the identification of the natural language used, the process of splitting the texts up from words into tokens and the subsequent normalization processes. Language identification is vital when it comes to isolation of Gujarati and English words in a sentence. Tokenization and normalization are some of the ways, which aid in transforming the text into a format which is convenient for findings[4].

Aspect-Based Sentiment Analysis Framework

In the suggested ABSA framework, we also include methods to extract features from the text as well as define the polarity or the sentiment tied to a given aspect. This entails washing the text to select aspect terms and using sentiment estimations to assess the sentiment polarity of each aspect.

Handling Code-Mixing

Regarding the issues of code-mixing, we present particular types of tokenization and use models that have been developed for the code-mixed corpora. This is helpful in making sure that the details regarding the language switching process is acknowledged, and the sentiment analysis is correct. We also employ the use of translation methods in the process if needed, that is translating the Gujarati components in to English so that there can be consistency in the evaluation of the sentiments.

Model Training and Evaluation

For sentiment analysis, both the machine learning and deep learning techniques are implemented. These are the models that are used to work on the preprocessed data set and fine-tuning of the hypermeters is done efficiently. The overall performance is bounded using the following measures of accuracy, precision, recall, and F1 score[5].



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Experimental Results: These examples also show that the accuracy of sentiment analysis greatly exceeds the traditional methods, which our experiments proved. Thus, compared to the prior approach, our method offers a better resolution to sentiment analysis due to the efficient understanding of code-mixed language[6].

Practical Applications

Our research has many practical implications as it is presented below. Improved polarity helps in enhancing social media analysis to give better information to businesses regarding what their customers are saying. It can also enrich feedback translation, and let the companies better know some special attitudes towards the corresponding elements of goods or services[7]. Thus, this research presents viable solutions to the problems faced by the ABSA in code-mixed Gujarati text, which is potentially helpful for the industries leveraging the sentiment analysis. Our contribution to the development of methodological approaches can be useful for further research on the study of MSA in the multifaceted context of multilingualism, which can act as the key to a better understanding of the modern tendencies in the multicultural environment that dominates in the multimedia context of today's world.

LITERATURE REVIEW

The field of sentiment analysis has developed during the recent several decades; however, recent years it was divided into more deep subfield – Aspect-Based Sentiment Analysis (ABSA) as the main focus of which is in the identification of particular aspects of the entities present in the texts. Similarly to the first function, it is not just a simple sentiment analysis where a text's sentiment is calculated; instead, ABSA finds sentiments directed at specific aspects mentioned in the text. This level of analysis is very useful in different applications, for example in customer feedback, customer reviews and social media. However, the complexity rises when the MSE includes the code-mixed text and especially the text that includes Gujarati and English languages.

Sentiment Analysis and ABSA

The basic research in the field of sentiment analysis began around the approaches to categories every document as positive or negative. This was succeeded by attempts to perform sentiment analysis at the level of having to consider the sentiment of the whole sentence before arriving at ABSA, where the emphasis was now placed on establishing the sentiment about particular aspects that can be found within the text (Ambreen 2020). ABSA involves two primary tasks: and aspect extraction, as well as sentiment classification[8]. Aspect extraction deals with recognizing the textual parts (aspects) concerned with a given area, and sentiment classification is the process of deciding on the polarity for every aspect. For these tasks, different approaches have been used varying from logical and rule-based to machine learning and deep learning. the association rule mining to extract the aspects from the product reviews whereas the recent methods use the neural networks and the attention mechanism to model the context and semantics (Manju et al., 2022)[9].

Code-Mixed Texts and Linguistic Challenges

Switching, which involves the use of two or more languages in the same conversation or in the same text is rife in multilingual communities. It complicates the sentiment analysis process due to a requirement of dealing with multiple languages in the same process. This is common in a lot of areas for instance in India, Such languages as Gujarati are uttered and written alongside English[10].

Handling Code-Mixed Texts in Sentiment Analysis

Several strategies have been proposed to handle code-mixed texts in sentiment analysis. These include:

Language Identification:

The simplest task to perform is the identification of these languages in the specified text. The techniques used range from basic such as dictionaries and n-grams to the contemporary machine learning models. Marcos et al. (2020)



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employed a supervised method based on the lexical and contextual aspect in order to predict languages in social media code-mixed text[11].

Translation

Another method is translating the code-mixed texts into a single language mostly English before analysis of data is carried out. This is beneficial for downstream processing but also means less accuracy and potentially much of the context, as translation models do not always completely represent mixed languages' semantics[12].

Specialized Tokenization

Newer tokenizers have been trained for code mixed data which is better capable of maintaining the language specific tokens' integrity. Later, Xinyi et al. (2023) suggested the use of language identification as a pre-processing technique along with custom tokenization for the code-mixed text[13].

Multilingual Embedding's

That is why to maximize the models' performance, the pre-trained multilingual word embeddings, such as MUSE (Gazi Imtiyaz et al. 2022) should be used. These embeddings can capture semantic similarity between words in the different languages to enhance the process of sentiment analysis for the code-mixed text[14].

Advances in ABSA for Code-Mixed Texts

Continued progress in NLP in the recent years has also seen new forms of ABSA models that are built to tackle the code-mixed text. Thus, works were devoted to studying the performance of various neural network architectures, such as gates as convolutional neural networks (CNNs), Recurrent Neural Networks (RNN), and transformers.

CNNs and RNNs

Discuss early neural models for ABSA pointed at applications of CNN for feature extraction and RNN for sequence modeling. Genta Indra et al. (2021) proposed to integrate CNNs with LSTM networks, which enables to learn both local and temporal features in text. These models were presented to allow for code-mixed data to feed by adding language-dependent features and embeddings[15].

Transformers and Attention Mechanisms

The coming up of transformer models and attention mechanisms changed the face of NLP including ABSA. Anupam et al. (2020) provided a clear proof of applying the construct called fine-tuned BERT models in the further analysis of the sentiment of the Indian social media using the texts written in Hindi-English code-mixed language[16].

Transfer Learning

Popular techniques such as transfer learning, where features are learned from huge databases and then specialized for certain tasks have also been used for ABSA in code-mixed text. It builds upon the general language understanding ability of the pre-trained models while fine tuning them for the code-mixed language features. It is employed by Gianni et al (2022) to enhance the results of the carriage of sentiment analysis on Indomishm-English mixture texts[17].

Practical Applications and Limitations

The areas in which ABSA can be practically applied for code-mixed texts lie in a wide range of possibilities of social media analysis and customer feedback analysis. It enables businesses to go beyond the simple evaluation of their business in terms of customer satisfaction but rather the dimensions of opinions that customers have concerning specific aspects of the business's products or services. This information may be used to design better products and develop and implement marketing and service delivery strategies that meet the customers' needs.



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METHODOLOGY

The framework to enhance the efficiency of Aspect-Based Sentiment Analysis (ABSA) for code-mixed Gujarati texts involves the following steps. The mentioned approach is a part of improving the efficiency of the Aspect-Based Sentiment Analysis for code-mixed Gujarati texts in each of the phases, several problems arise from the linguistic and structural characteristics of the code-mixed language. This section describes the process of data collection and preprocessing through to model training and assessment, laying out the new methods used to address code-mixing[18].

Data Collection and Preprocessing

Data Collection

The initial step of our proposed methodology is the data gathering that involves the creation of a large code-mixed Gujarati corpus. The data was collected using social media platforms such as Twitter, Facebook, new groups, and customers' review sections. This diverse data set also contains a number of topics which guarantees the presence in the resulting image of several aspects and different attitudes. Due to the absence of code-mixed datasets in the literature, the current study also followed the process of manual annotation which involved marking of the text with aspects and their associated sentiment polarity[19].

Preprocessing

Data cleaning is an important step because it involves transformations into the raw text data that is usually collected. Our preprocessing pipeline includes the following steps: Our preprocessing pipeline includes the following steps::

Language Detection

Primary as it is to identify the languages present in each segment is, it is also just as simple. By using dictionary based methods and machine learning models established to identify Gujarati and English word within the same text. This step ensures that there is right separation and with right treatment different language components are got[20].

Tokenization

Splitting the text into one or many parts by using space or by considering a word or a phrase at a time is called tokenization. Most of the standard tokenizers are ineffective when it comes to code-mixed text data because of different vernacular language's punctuation and grammatical patterns. Therefore, we came up with a novel tokenizer that is sensitive to different languages while maintaining the quality of tokens pertaining to a specific language[21].

Normalization

Normalization entails preprocessing the text to decrease the variation resulting from the differences in writing style between the samples. In most cases, variations in both Gujarati and English are quite intricate and together with the rules mentioned above, we employed other techniques to standardize the way words are written[22].

Translation

In some cases where certain analytical perspectives are relevant, it might be useful to translate the Gujarati components to English. Due to the variations in languages, we were able to use translation models to obtain parallel datasets. This step, however, is done selectively in order not to lose cultural and contextual contents[23].

Aspect-Based Sentiment Analysis Framework

Aspect Extraction

Aspect extraction identifies the specific features or components (aspects) discussed in the text. We employed a hybrid approach combining rule-based methods and machine learning models:



**Shyam Viththalani and Krunalkumar Patel****Rule-Based Methods**

These involve predefined linguistic patterns and keywords to identify aspects. For example, product reviews often mention aspects like “battery,” “screen,” or “performance.” Such rules help in quickly identifying common aspects[24].

Machine Learning Models

We trained machine learning models (e.g., Conditional Random Fields, CRFs) to learn from annotated data. These models can recognize more complex and context-dependent aspects that rule-based methods might miss[25]. Once aspects are identified, the next step is to determine the sentiment associated with each aspect. We used a combination of traditional machine learning classifiers and deep learning models:

Machine Learning Classifiers

Methods such as Support Vector Machines (SVM) and Random Forests are learned from the feature vectors obtained from text where these are n-grams, part-of-speech tags, and syntactic dependencies.

Deep Learning Models

To extract semantic and contextual information we used Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks. These models are especially useful when analyzing the specifics of second language texts inextricably containing English language fragments.

Handling Code-Mixing**Specialized Tokenization**

Since the proposed custom tokenizer is to work with code-mixed texts, it is able to identify and maintain language-bound features. The above tokenizer has the capability of distinguishing between Gujarati and English tokens so as to accurately represent a scenario that may have both types of tokens such as in; “ I am from Gujarat, India ”.

Multilingual Embeddings

The semantic translations were based on a comparative assessment of two multi-lingual pre-trained word embedding models: MUSE & LASER. Hence, these embeddings mainly offer a common representation of words in varying languages, which boosts the model’s performance in comparing and analyzing code-mixed texts[26].

Transfer Learning

In transfer learning, we train models on our code-mixed set fine-tuning pre-trained models. We employed multilingual BERT (mBERT) and XLM-R as they were developed from large multilingual corpora and further optimized by the current research on the annotated code-mixed dataset. This approach builds on the ability of such models to understand and learn the general language while fine-tuning them for the dialect of Gujarati-English code-switching.

Training

Stratified k-fold cross validation was used to train our models in order to get better evaluation. Fine-tuning of the hyperparameters to increase practical performance on significant characteristics of the training set was performed with up to six degrees of freedom where possible, including learning rate, batch size, number of layers of the deep learning models, and so on[27].

Evaluation Metrics

At the end of model training, accuracy, precision, recall, and F1-score were considered as the final metrics for the evaluation of the proposed models. Such measures give a general evaluation of model performance, the efficiency of comparison of aspects as well as the effectiveness of sentiment assessment.



**Shyam Viththalani and Krunalkumar Patel****Comparative Analysis**

We also compared our method with baseline models and some of the existing methods in Sentiment Analysis of code-mixed texts. This comparative analysis of our and other works pointed out that the benefits of the used methodology could be observed in aspect extraction and sentiment classification error rate enhancement[28].

Experimental Results

The proposed methodology learned from these experiments demonstrated the efficiency of this method over the traditional approaches applied to code-mixed Gujarati text. Custom tokenization, available in the enterprise version of topic, as well as fine-tuned models such as multilingual embeddings and transfer learning models boasted of improved aspect extraction and sentiment classification significantly. The findings revealed that due to greater resource availability and better understanding of the context, there was more accuracy and thereby better ability of dealing with code-mixed language which is intrinsically context sensitive.

Practical Applications

The utilization of our research findings is indeed profound. The improvement of ABSA for code-mixed texts can help in social media monitoring with delivering more detailed information about customers' opinions to businesses. It can also enhance the assessment of customer feedback that can generate information of customers' specific attitudes towards some aspects of a business firm's product or service hence assist companies in enhancing their decisions that result in improved customer satisfaction.

CONCLUSION

The proposed methodology of ABSA for code-mixed Gujarati texts improves the overall accuracy of sentiment detection because it encompasses various challenges related to amalgamation of codes from two different languages. Said method involves the use of not only a custom tokenizer, but also language detection methods that would allow for a proper splitting of text into Gujarati and English parts. This means that procurements done will be of high quality, which is key to being used for analysis. For the aspect extraction, we employ a rule based and model based approach while for the sentiment classification, we employ deep learning with special focus on attention mechanism. Such innovations enhance the specificity of the method of sentiment analysis in terms of specific aspects. It is also noteworthy that the proposed models utilize multilingual embeddings as well as transfer learning methods that can also help address the problems arising from code-mixed texts by enabling proper semantic analysis of the texts in different languages. The outcomes of our experimental evaluation indicate that improvements over conventional techniques are achieved and depicted an improvement in sentiment analysis. Some benefits of our study are the enhanced monitoring of post content that might be potentially damaging for a company and the enhancement of customer feedback analysis for gaining enhanced knowledge about people's opinions and behaviors. This methodology helps to develop the tools for industries involved with multilingual data, leading to the improvement of the decision-making and customers' satisfaction. The present work can be extended into the subsequent research in using these techniques incorporating other languages and environmental applications.

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**Shyam Viththalani and Krunalkumar Patel****Table 1. Aspect Extraction Techniques**

Technique	Description	Tools/Methods Used
Rule-Based	Identifying aspects using predefined linguistic patterns and keywords	Custom rules
Machine Learning	Training models to recognize complex and context-dependent aspects	CRFs, Feature extraction methods

Table 2. Sentiment Classification Models

Model Type	Description	Tools/Methods Used
Machine Learning	Using feature vectors (n-grams, POS tags, etc.) to classify sentiment	SVM, Random Forest
Deep Learning	Utilizing neural networks to capture semantic and contextual information	CNNs, LSTMs
Attention Mechanisms	Enhancing model performance by focusing on relevant parts of the text	Attention layers

Table 3. Code-Mixing Handling Techniques

Technique	Description	Tools/Methods Used
Specialized Tokenization	Custom tokenizers for recognizing and preserving language-specific structures	Custom tokenizer
Multilingual Embeddings	Using embeddings that capture semantic relationships across languages	MUSE, LASER
Transfer Learning	Fine-tuning pre-trained models on specific code-mixed datasets	Multilingual BERT (mBERT), XLM-R

Table 4. Code-Mixing Handling Techniques

Model	Accuracy (%)	Precision (%)	Recall (%)	F1 Score (%)
Baseline Model	75.2	73.4	71.6	72.5
Proposed ML Model	82.6	81.2	79.8	80.5
Proposed DL Model	88.4	87.0	86.1	86.5
Transfer Learning Model	91.2	90.1	89.5	89.8





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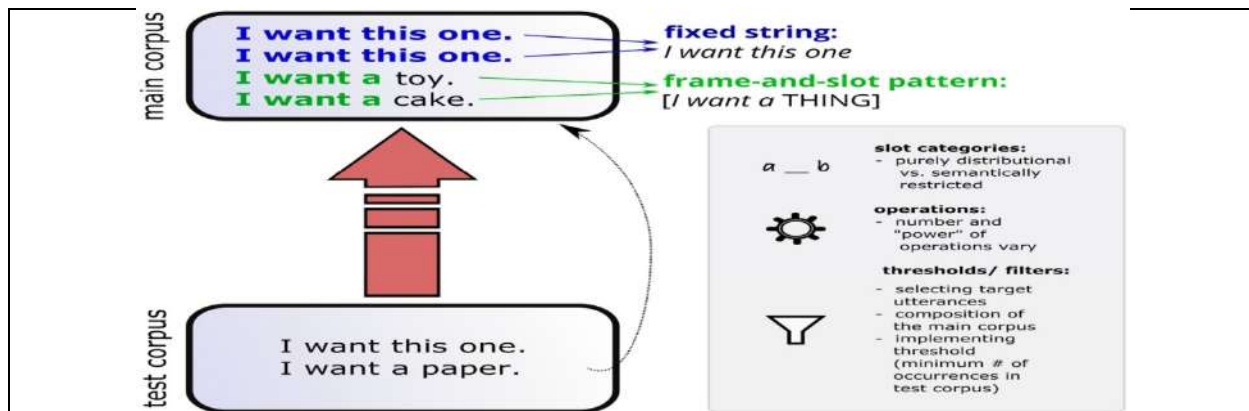


Fig. 1 TB method

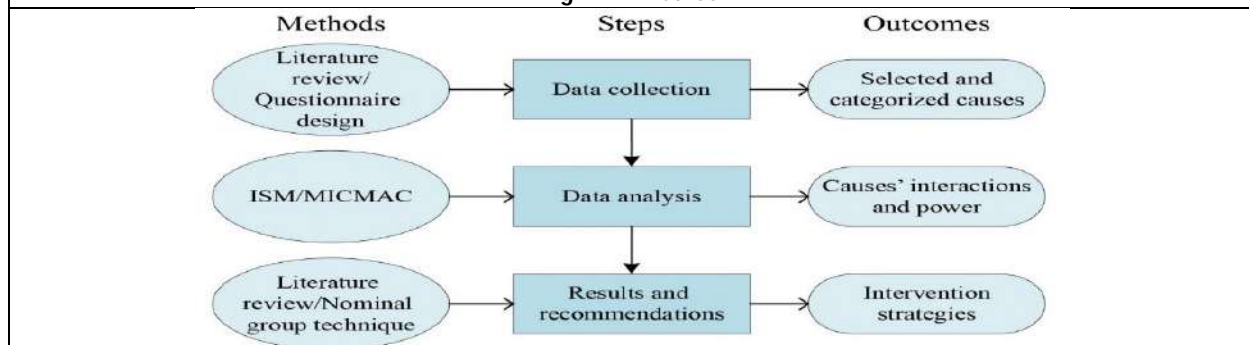


Fig. 2 Flowchart diagram of the research process





Effect of Complex Training on Physiological Variables of Team Game Players of CUPB

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ABSTRACT

The study aims to investigate the effect of complex training on the physiological variables (resting heart rate and blood pressure) of team game players of CUPB. A total of 24 subjects of handball and volleyball players (12 subjects in the control group and 12 in the experimental group) enrolled in various master's degree programs at the Central University of Punjab, Bathinda, aged between 21 and 26 years, were selected for the study. A purposive sampling method was used to fulfill the study's objectives. The experimental group underwent complex training; the other group acted as a control. Before and after the training, the subjects were tested on physiological variables (resting heart rate and blood pressure) using standard tests and procedures. ANOVA was used to determine the significant difference existing between pre-test and post-test on physiological variables. The result of the study proved that the effect of complex training decreased the physiological variables (resting heart rate and blood pressure) of team game players of CUPB.

Keywords: Complex training, Physiological variables, Resting heart rate, Blood pressure





INTRODUCTION

Enhancing athletic performance is aided by sports training. Like other forms of human performance, sports performances are also the result of the athlete's entire personality. A person's physical, physiological, social, and psychological characteristics make up their personality. Consequently, to enhance sports performance, a sportsperson's social and psychological qualities must be developed in addition to their physical and physiological attributes (Hardayal Singh, 1991). A complex training method is similar to a contrast training method, which uses strength and plyometric exercises in a single session (Cormier et al., 2020). There is a vast difference in the way how the exercises are performed. In the complex training method, a complex set comprises a strength exercise (e.g., Bulgarian split squat) immediately followed by a plyometric exercise (e.g., Split jump) set by set. Resting heart rate is the total number of heart beats per minute. The automatic nervous system controls the heart rate, which provides the Sino-vial artery node with parasympathetic or vagus nerves and sympathetic or acceleratory nerves (Larry, 1982). Blood pressure is the force that blood exerts on the walls of blood vessels. The force that blood applies to blood vessel walls is known as blood pressure. It is essential for ensuring proper tissue perfusion during physical activity and rest periods.

METHODOLOGY

Subjects And Variables

The purpose of the study is to investigate the effect of complex training on the physiological variables (resting heart rate and blood pressure) of team game players of CUPB. A total of 24 subjects of handball and volleyball players (12 subjects in the control group and 12 in the experimental group) enrolled in various master's degree programs at the Central University of Punjab, Bathinda, aged between 21 and 26 years, were selected for the study. A purposive sampling method was used to fulfill the study's objectives. The experimental group underwent complex training; the other group acted as a control. Resting heart rate was measured using the palpitation method, and blood pressure was measured using a sphygmomanometer.

Training Protocol

The experiment group underwent complex training twice weekly for six weeks. The workout lasted approximately 45 minutes in everyday training sessions, including warming up and limbering down. The control group did not participate in any particular training program or strenuous physical exercises apart from their activities.

Experimental Design and Statistical Technique

The study was formulated as a random group design consisting of pre-test and post-test. The subjects (n=24) were randomly selected from the Central University of Punjab handball and volleyball team. Two groups were selected: the Control Group and the Experimental Group. The pre-test was conducted on all subjects' physiological variables. Then, the experimental group underwent training for six weeks. The post-test was performed on the dependent variables after the training period. ANOVA was used as a statistical technique to determine the effect of complex training on selected physiological variables between controlled and experimental groups. Table-I shows that the pre-test mean and standard deviation on the experimental and control groups' resting heart rates are 68.083 ± 1.621 and 69 ± 1.279 , respectively. The obtained 'F' ratio value of 0.138 for the pre-test mean on resting heart rate of the experiment and control group was less than the required table value of 4.30 for the degrees of freedom 1 and 22 at 0.05 confidence level. It reveals a statistically insignificant difference between the experiment and control groups during the pre-test period. The post-test mean and standard deviation on resting heart rate of the experiment and control group are 64.666 ± 1.669 and 68.25 ± 2.094 , respectively. The obtained 'F' ratio value of 21.477 for the post-test mean on resting heart rate of the experiment and control group was more significant than the required table value of 4.30 for the degrees of freedom 1 and 22 at 0.05 confidence level. It reveals a statistically significant difference between the experiment and control groups during the post-test period.



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Table II shows that the pre-test mean and standard deviation on blood pressure(systolic) of the experiment and control group are 114.583 ± 3.604 and 115.416 ± 2.968 , respectively. The obtained 'F' ratio value of 0.382 for the pre-test mean on blood pressure(systolic) of the experiment and control group was less than the required table value of 4.30 for the degrees of freedom 1 and 22 at 0.05 confidence level. It reveals a statistically insignificant difference between the experiment and control groups during the pre-test period. The post-test mean, and standard deviation on the experiment and control group's blood pressure(systolic) are 110 ± 4.156 and 114.666 ± 3.446 , respectively. The obtained 'F' ratio value of 8.965 for the post-test mean on blood pressure(systolic) of the experiment and control group was more significant than the required table value of 4.30 for the degrees of freedom 1 and 22 at 0.05 confidence level. It reveals a statistically significant difference between the experiment and control groups during the post-test period. Table III shows the pre-test mean and standard deviation of the experiment and control group's blood pressure(diastolic) are 78.166 ± 2.329 and 78.75 ± 2.137 , respectively. The obtained 'F' ratio value of 0.409 for the pre-test mean on blood pressure(diastolic) of the experiment and control group was less than the required table value of 4.30 for the degrees of freedom 1 and 22 at 0.05 confidence level. It reveals a statistically insignificant difference between the experiment and control groups during the pre-test period. The post-test mean and standard deviation on the experiment and control group's blood pressure(diastolic) are 74 ± 2.174 and 78.666 ± 2.461 , respectively. The obtained 'F' ratio value of 24.225 for the post-test mean on blood pressure(diastolic) of the experiment and control group was more significant than the required table value of 4.30 for the degrees of freedom 1 and 22 at 0.05 confidence level. It reveals a statistically significant difference between the experiment and control groups during the post-test period.

DISCUSSION ON FINDINGS

The study aimed to determine the effects of complex training on physiological(resting heart rate and blood pressure) parameters. Comparing the experimental group to the control group, the study indicated that the complicated training strategy lowered the experimental group's resting heart rate. The resting heart rate was notably affected by complex training; it was 68 beats per minute before training and decreased to 64 beats per minute following training. The research listed below corroborates my investigation's conclusions. The impact of complicated and contrast training on male football players' physiological and biomotor characteristics was investigated by Kanniyar *et al.* (2013). The resting heart rate significantly decreased after complex training. Babu *et al.* (2023) examined the effects of varying plyometric training intensities on volleyball players' resting heart rates and VO₂ max. Additionally, the resting heart rate decreases after plyometric exercise. Raju *et al.* (2023) looked at the effects of several plyometric training intensities on volleyball players' resting heart rates and spiking. The findings indicated that the resting heart rate had significantly decreased. The study's findings demonstrated that the experimental group's blood pressure dropped as a result of sophisticated training as compared to the control group. In the experimental group, there was a drop in both diastolic and systolic pressure. The studies that follow bolster the conclusions of my research. The impact of complicated and contrast training on men's football players' physiological and biomotor characteristics was studied by Kanniyar *et al.* (2013). It also shows how complicated exercise might lower blood pressure.

CONCLUSIONS

The study's conclusion showed that the complex training decreased the experimental groups' (volleyball and handball players of CUPB) resting heart rate and blood pressure compared to the control group.

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Table.1: Anova For Resting Heart Rate

	Experiment Group	Control Group	S O V	Sum of Squares	df	Mean Squares	'F' Ratio
Pre-Test MEAN SD	68.0833	69.0000	B	5.042	1	5.042	0.138
	1.62135	1.27920	W	46.917	22	2.133	
Post-Test MEAN SD	64.6667	68.2500	B	77.042	1	77.042	21.477*
	1.66969	2.09436	W	78.917	22	3.587	

(*The required table value is 4.30 with df 1 and 22)

Table.2: Anova For Blood Pressure(Systolic)

	Experiment Group	Control Group	S O V	Sum of Squares	df	Mean Squares	'F' Ratio
Pre-Test MEAN SD	114.5833	115.4167	B	4.167	1	4.167	0.382
	3.60450	2.96827	W	239.833	22	10.902	
Post-Test MEAN SD	110.0000	114.6667	B	130.667	1	130.667	8.965*
	4.15605	3.44656	W	320.667	22	14.576	

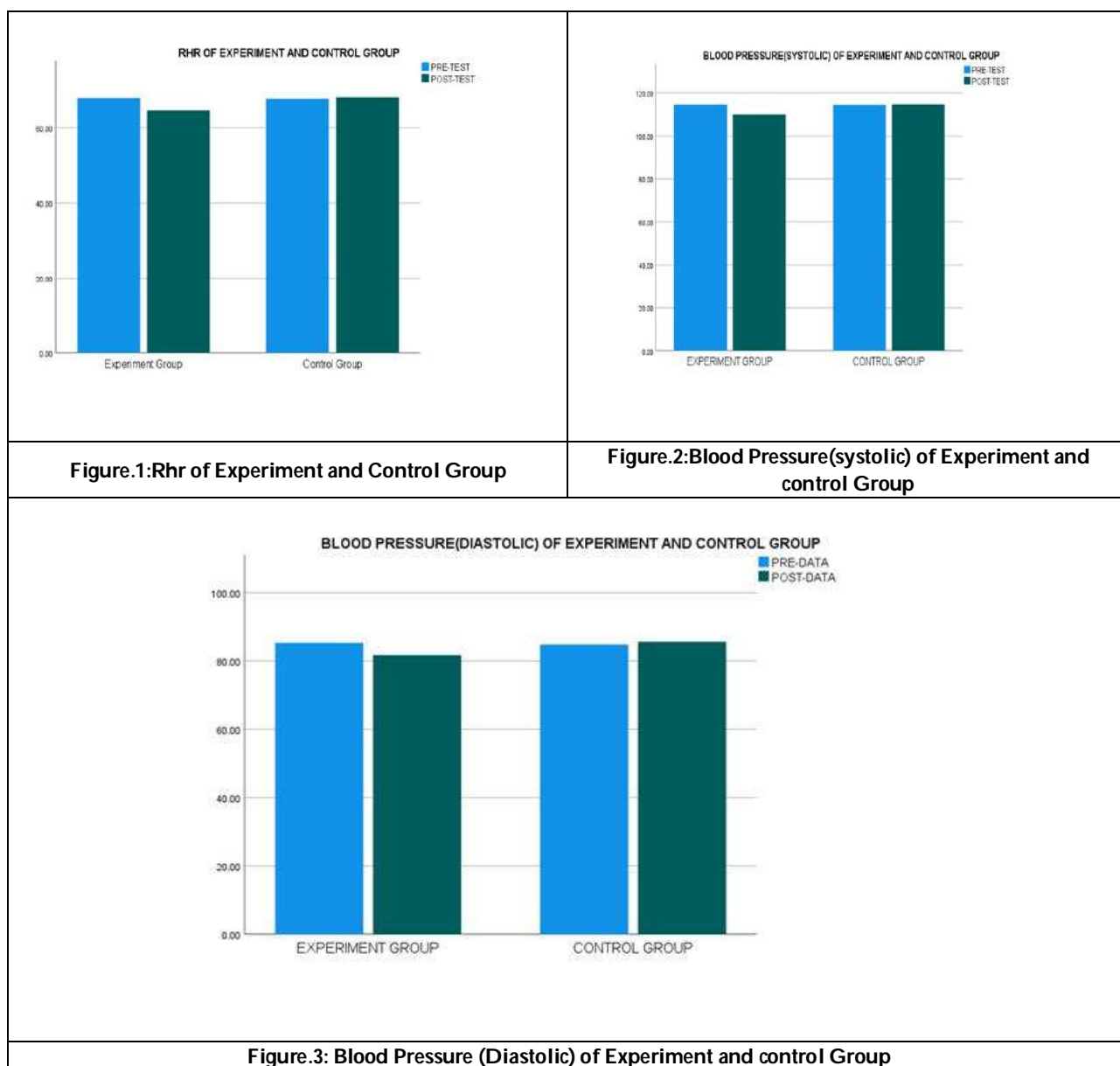
(*The required table value is 4.30 with df 1 and 22)

Table.3: Anova For Blood Pressure(Diastolic)

	Experiment Group	Control Group	S O V	Sum of Squares	df	Mean Squares	'F' Ratio
Pre-Test MEAN SD	78.1667	78.7500	B	2.042	1	2.042	0.409
	2.32900	2.13733	W	109.917	22	4.996	
Post-Test MEAN SD	74.0000	78.6667	B	130.667	1	130.667	24.225*
	2.17423	2.46183	W	118.667	22	5.394	

(*The required table value is 4.30 with df 1 and 22)







A Comprehensive Review of Vitamin D Deficiency Conditions in Clinical Practice: Diagnosis, Treatment, and Prevention

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ABSTRACT

Throughout the world, Vitamin D insufficiency is an extremely prominent illness by means of potentially dangerous outcomes. A significant risk to the overall health of people with cystic fibrosis (CF) is vitamin D deficiency. Deficiency is mostly brought on by poor sun exposure, insufficient ingestion, and malabsorption of fat - soluble vitamins. The negative consequences of low vitamin D on health, notably a greater probability of infections, autoimmune disorders, cancer and hypertension. Different standard urge supplementing with vitamin D for all age groups. However, there is a chance of using vitamin D supplements won't work well enough, and there could be negative side effects as well.

Keywords: Vitamin D, Vitamin D deficiency, Pregnancy, Bone Health, Immune system.

INTRODUCTION

Around the world, vitamin D insufficiency is widespread. The body takes fewer Phosphate and Calcium despite inadequate amounts of vitamin D due to it exists little Phosphate and Calcium supplied to support strong bones. A lack of vitamin D can cause osteomalacia in individuals or rickets in youngsters, which is a bone disease. Bone weakness are the outcome of osteomalacia, a condition in which the human body cannot adequately collaborate with Calcium and other minerals to form bones. The body might attempt to raise its inadequate Calcium concentration by



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producing a greater amount of parathyroid hormone.[1] Fat-soluble vitamins include vitamin D. It plays numerous vital roles in the body and is found in plants, animals, and yeast. In a technical sense, it belongs to the category of hormones since the skin synthesizes it using sunshine[2].

Vitamin D Deficiency

Most authors characterize vitamin D insufficiency in a range of serum/plasma 25(OH)D values not more than 75 nmol/L (or 30 ng/ml)[3]. First, Having a cut-off of fewer than 25 or less than 30 nmol/L indicates severe vitamin D inadequacy, which greatly raises the risk of osteomalacia and dietary rickets[4,5]

Sources

Sources of Vitamin D includes

- Natural sources: Exposure to sunlight, Sardine, Mackerel, Tuna, Egg yolks, Mushrooms
- Fortified foods: Milk, Yogurt, Cheese, Cereals, Orange juice, Butter, Margarine
- Supplements: Vitamin D₂, Drisdol liquid supplements, Multivitamins, Vitamin D₃[6]

Synthesis of Vitamin D

While subjected to UVB rays, the human body produces vitamin D in the skin, as seen in Figure 1.

Daily Requirement

Children And Adult The Academy of Medicine suggests 200 IU of vitamin D for children as well as adults who are under the age of fifty, 400 IU for elderly of 51 to 70 years old, and 600 IU for persons of 71 years old or over as a sufficient daily dose[2]. Still, almost all professionals believe that adults and children need between 800 and 1000 IU of sun exposure per day. [8,9] Breast Fed Infants One litre of human milk contains about 20 IU of vitamin D, and females who have insufficient levels of vitamin D give their breastfed children far less. Lactating women's milk would contain sufficient amounts of vitamin D₃ to meet an infant's demands if they were given 4000 IU of the vitamin each day. Furthermore, the extent of 25-hydroxyvitamin D would increase above 30 ng per milliliter. [10]

Factors Affecting Vitamin D Status

A person's vitamin D levels might be altered by genetics, weight, and characteristics that affect the epidermal synthesis of vitamin D, such as complexion and ethnicity, age, season, and latitude, as well as by wearing clothing that protects the skin from the sun and using sunscreen. Several studies have indicated that a significant factor is connected to persistent medical conditions, such as psychological conditions. [11]

Causes of Vitamin D Deficiency

Individuals receive their vitamin D mostly due to being exposed to sunshine [12]. Whatever lowers the quantity of ultraviolet (UVB) rays from the sun that enters the outermost layer of the planet or that blocks UVB radiation from entering the body may influence the epidermal development of vitamin D₃[13]. More tone of the skin significantly decreases the mechanism of vitamin D₃ production [14]. In contrast, sunscreens ingest 99% of absorbed ultraviolet (UVB) rays with a sun protection factor of 15 light, which indicates that when applied topically, they will 99% minimize the quantity of vitamin D₃ generated within the skin.[15]

Prevalence

Extremely significant proportions of inadequate levels of vitamin D are reported in several countries across the world. More than 20% of people in Afghanistan, Pakistan, Tunisia, and India had concentrations of 25(OH)D beneath 12 ng/ml, or 30 nmol/L. For instance, 490 million Indians are considered to be deficient in vitamin D.[16,17] Vitamin D deficiency may affect 85–99% of hemodialysis individuals who have persistent kidney dysfunction patients, liver receivers of transplants, and individuals with a liver condition.[18,19,20]



**Implications of Vitamin D Inadequacy**

Insufficient levels of vitamin D during childhood may retard their growth to reach their full bone mass. The consequences of vitamin D inadequacy on the skeleton are less serious in grownups. Secondary hyperparathyroidism can reduce bone mineral density, which can lead to osteoporosis or exacerbate, because it stimulates Calcium from the skeleton. Because of this, people with osteomalacia frequently complain of bone discomfort[21,22]. Non-specific collagen vascular diseases like myositis, fibromyalgia, and chronic fatigue syndrome are commonly mistreated in patients. In accordance with assumptions, 40–60% of fibromyalgia affected might have symptoms of osteomalacia and a vitamin D deficit[22,23].

Diagnosis of Vitamin D

High-risk vitamin D will be prescribed to individuals whose insufficiency is assessed. To assess whether vitamin D is sufficient or insufficient, serum 25-hydroxyvitamin D is evaluated.^[24]

Purpose of Vitamin D**The Consequence On The Mineral Density of Bone**

Insufficient bone mineral density is a significant increased risk of osteoporosis fractures and is linked with vitamin D insufficiency[25,26]. Assessing daily 700 or 800 IU of vitamin D3 to a placebo, older women (>65 years) demonstrated moderate but substantial improvements in the density of bone minerals in the lumbar spine and femoral neck [27,28].

Depression And Schizophrenia

Vitamin D insufficiency has been associated with elevated rates of depression and schizophrenia [29]. Sustaining adequate levels of vitamin D throughout the gestation period and the initial years of life expectancy may be essential for brain growth in addition to the preservation of later-life mental function in order to fulfill the transcriptional functions of the binding site for vitamin D in the brain [30]. Elevated conveying of vitamin D receptors (VDR) in numerous locations of the brain, such as the prefrontal and frontal cortices, is known to be necessary for controlling mood and may decrease the development of depression [31]. Vitamin D is also thought to have a part in depression by perhaps maintaining glutamate-γ-aminobutyric acid and Calcium levels [32].

Pregnancy

A greater dosage of vitamin D is now advised did not seem to offer additional benefits beyond maybe lowering gestational diabetes, despite the fact that supplementing with vitamin D may help lower birthweight in babies, preeclampsia, and gestational diabetes [33]. Recent research, however, indicates that a lack of vitamin D is especially dangerous for women and can lead to complications of pregnancy as preeclampsia and gestational diabetes [34]. Elevated vitamin D concentrations are being demonstrated to dramatically lower the chance of complications during pregnancy; this benefit rises when the target amount is increased from 20 to 40 or 50 ng/mL[35]. "Greater serum vitamin D levels during pregnancy have reduced the risks of preterm birth," the FDA recently approved.

Cancer

A connection with low levels of vitamin D and an increased threat of developing various kinds of tumours has led to research into supplementing with vitamin D as a tumour preventive method [36]. The results of several investigations provided the basis for this. In 1980, Calcitriol was first thought to have the ability to stop the proliferation of cancerous melanoma cells [37]. A lower cancer death rate has been associated with more sun exposure, according to ecological research [3]. The anticancer potential of Vitamin D for a range of cancers has been the subject of investigations throughout the years, with differing levels of achievement [38]. As a result, it was unknown whether Vitamin D prevented cancer in any way [39].

Diabetes

Vitamin D insufficiency was more widespread among people with Type 1 diabetes (T1DM) compared to healthy individuals, according to multiple studies that have connected diabetes to 25(OH)D amounts^[40]. Prenatal vitamin D exposure in the foetus was found to be substantially associated with a greater chance of type 1 diabetes, as were



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lower gestational 25(OH)D levels [41] or a diet deficient in vitamin D-fortified foods [42]. Infants who get vitamin D administration [43] or vitamin D-enriched margarine [42] have been found to have a reduced prevalence of type 2 diabetes that is dependent upon insulin. Taking supplements around 7 and 12 months of development nearly doubled the danger of type 1 diabetes [44]. Multiple teen studies have found there is no connection with the 25(OH)D level and the start of T1DM [45].

Cardiovascular Disease

Epidemiological studies have demonstrated the existence of a negative relationship between PTH levels and 25(OH)D levels, indicating that high-normal and raised concentrations of PTH are linked to an elevated chance of cardiac incidents and death.[46] Myocardial hypertrophy and pro-arrhythmia are two of the heart's consequences of PTH, it also raises blood pressure. Consequently, PTH reduction brought on by vitamin D might reduce the incidence of cardiac problems. [47]

Immune System

The vitamin D hormone performs paracrine and autocrine actions in addition to endocrine effects. Through the use of enzymes and VDR, immune-competent cells like B and T lymphocytes, dendritic cells, and macrophages may produce 1,25(OH)₂D using their precursor, 25(OH)D. The ratio of Th1 and Th2 cells in the immune system and acquired immunity are both significantly impacted by 1,25(OH)₂D. TNF α improves the phagocytosis rate, monocyte macrophage differentiation, and macrophage lysosomal activity of enzymes.[48]

Rheumatoid Arthritis

Apart from bacterial infections, vitamin D contributes to the etiology of autoimmune diseases. The conditions multiple sclerosis (MS), inflammatory bowel illness, rheumatoid arthritis, also called RA, and diabetes with type 1 have both been associated with higher latitudes.[49,50] Since Th17 cells play a major role in the pathophysiology of RA, it is interesting to see how vitamin D deficiency affects RA.[50]

Inflammatory Bowel Disease

Many factors, some unique to bowel illness and others common to those without IBD, might lead to vitamin D deficiency in IBD patients. They involve insufficient sun exposure as a result of lifestyle choices or chronic symptoms of underlying medical conditions that limit physical activity, inadequate absorption, inadequate conversion of vitamin D to its active forms, increased excretion, and increased catabolism, as well as Insufficient dietary intake due to indicators of intestinal inflammation [51]. Insufficient vitamin D concentrations in certain IBD patients can also be caused by inadequate dietary consumption [52].

Common Symptoms[53]

- Fatigue and tiredness
- Decreased wound healing
- Anxiety and depression
- Muscle soreness
- Pain in back and bones
- Alopecia

Prevention And Management

Generally adults in their middle years have a greater probability to be poor in vitamin D because they use sun protectors more often and less frequently exposed to the sun. As a result, studies show that at least 1000 IU, likely between 1500–2000 IU/day, are required to raise blood (OH) D content over 30 ng/ml. Insufficient sun exposure as well as vitamin D utilization are the primary causes of vitamin D insufficiency. The first characteristic sign of gluten sensitivity is vitamin D deficiency. Although such people consume continuous oral vitamin D supplementation at prescribed doses, their plasma vitamin D levels do not enhance.[54] Individuals under the age of 65 who are not getting enough exposure to the sun throughout the whole year ought to consume 600–800 international units of





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vitamin D-3 every day to avoid insufficiency. To avoid insufficiency and reduce the possibility of injuries and falls, individuals who are 65 years of age and above should ingest 800–1000 international units of vitamin D3 every day [55]. Since many individuals don't get enough dietary intake of vitamin D in addition to sunlight, vitamin D supplements are usually vital for sustaining adequate vitamin D level.[56] A secure and easily accessible amount of 25 µg of vitamin D3 (1,000 IU) raises the plasma concentration of the 25-hydroxyvitamin D [25(OH)D] about 15–25 nmol/L on an average basis (over weeks/ months)^[43,44]. It must be mentioned that the serum concentration of 25(OH)D responds nonlinearly, rising substantially with less than 1 IU/day of vitamin D and flattening out with over 1 IU/day[3,57]. The sunshine vitamin comes in a number of ways. Vitamin D3 (cholecalciferol) is a suggested therapy since it is being shown to be considerably more efficient over vitamin D2 (ergocalciferol) in achieving the optimum amount of 25-hydroxyvitamin D [58].

Toxicity

In the previous years or so, the consumption of vitamin D supplements has increased substantially. The general population is becoming more aware of the dangers of extrinsic elevated levels of vitamin D and inappropriate use of over-the-counter vitamin D. Elevated levels of serum 25(OH)D or unbound 1,25-dihydroxyvitamin D [1,25(OH)2D] levels brought on by these situations may cause elevated Calcium levels and, eventually, hypercalcemia.[59] Furthermore, intrinsic causes of elevated levels of vitamin D can include increased 1,25(OH)2D synthesis due to lymphomas or granulomatous conditions. [60,61]

CONCLUSION

Lack of vitamin D is becoming recognized as a significant medical problem because maintaining both skeletal and non-skeletal processes requires vitamin D of the body, particularly in women. Both the pregnant woman and the foetus may suffer if vitamin D amounts are inadequate through pregnancy. Numerous non-skeletal diseases, including cancer, diabetes, tuberculosis, and diarrhoea, are being demonstrated to gain advantages from enough solar exposure, vitamin D supplements, and diets high in vitamin D. Despite being blessed with the ability to receive sufficient exposure to sunlight, 70–100% of Indians fail to acquire sufficient vitamin D from their diet. Enriching everyday foods to maintain appropriate vitamin D levels is an extremely practical, population-specific approach.

Conflicts of Interest

The authors have declared no conflicts of interest. All of the co-authors have evaluated the article, agree with its contents, and have no financial conflicts to declare. The submission is our original work, and we certify that no other magazine is considering it for publication.

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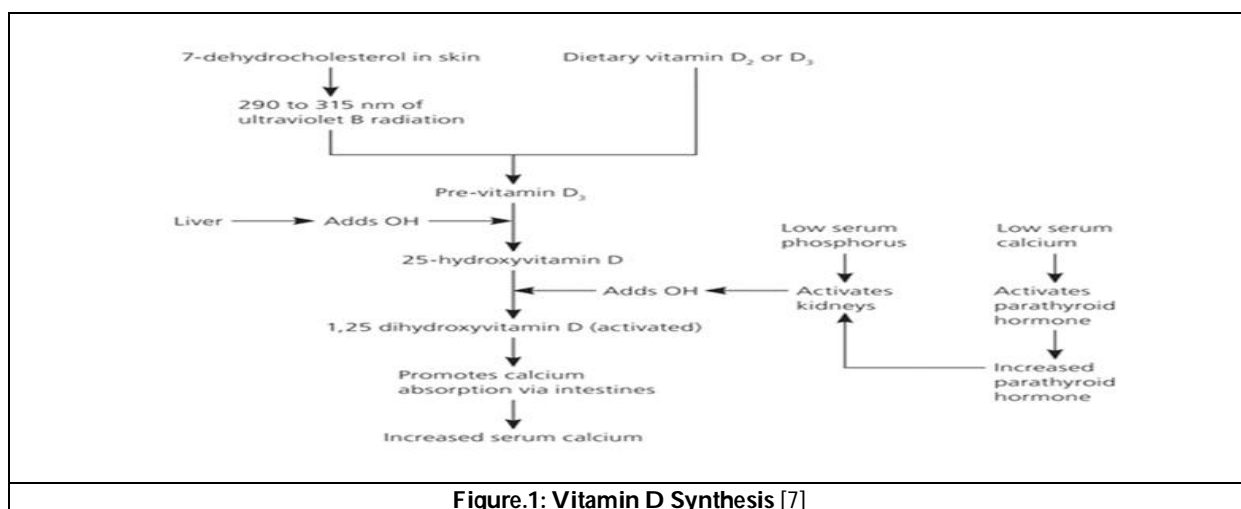


Figure.1: Vitamin D Synthesis [7]





Using Graphic Organizer to Develop Metacognitive Awareness in Mathematics Class Room of Elementary School Students

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ABSTRACT

Metacognition is refer as cognition about cognition and one's aware about ones' cognition. This term coined by John Flavell in twenty centuries. It has two dimensions one is knowledge of cognition and second is regulation of cognition. Metacognition is higher level of cognition. Graphic Organizer is very effective tool for enhancing and promoting meaningful learning. It improve the result of student's performance and achievements in each and every aspect of learning.. Investigator present study focus on to find out the effect of graphic organizer strategy on metacognitive awareness of elementary school students. Investigator select pre-test, post-test, two group design for present study. Result reveal that graphic organizer metacognitive strategy enhances the metacognitive awareness of elementary students. There is significant difference between the metacognitive awareness of elementary students taught through convictional method and graphic organizer metacognitive strategy.

Keywords: Graphic Organizer, Metacognition, Metacognitive strategies, Metacognitive awareness

INTRODUCTION

Education is a strong tool for social change and any meaningful development for society. Today's era needed more innovation in education, innovation effect all social, cultural, economic, psychological aspects of education. This era is also known as 'knowledge revaluation era' knowledge revaluation refers to create and construct new knowledge in every aspect of life. New knowledge is connected with previous knowledge, experiences, and interest of learner. Education is a lifelong journey for any learner in formal education setup. Supporting our students' development into productive, self-sufficient adults is one of the main goals that education must address. A key consideration when thinking about education is students' capacity to employ tactics that guide their motivation towards action in the



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direction of the meta-proposal. This is when metacognition—knowledge about knowledge itself—comes into play. It is this component that oversees the effective direction, monitoring, regulation, organisation, and planning of our talents once they have begun to function. By raising awareness of one's own cognitive processes and self-regulation, metacognition assists students in developing into autonomous learners who can control their own learning and apply it to any aspect of their lives. As we can see, it is a deliberate, high-level thinking exercise that enables us to examine and consider our own learning processes and tactics. As a result, we must address the issue of learning and knowledge, which is becoming more and more pressing, from the standpoint of students' active participation. We must employ appropriate cognitive learning techniques to meet these "learning to learn" goals. Among these, we might emphasise those focused on critical thinking, metacognitive strategy development, and self-learning. Metacognition is an important aspects of knowledge revolution. Eurasianists and educational phycologist have realized the importance of metacognition and its learning strategies. Metacognition means 'thinking about thinking', it is an ability to evaluate a cognitive task to determine what might be the best way to accomplish the task. "Metacognition was originally referred to as the knowledge about the regulation of one's own cognitive activities in learning process" (Flavell, 1979; Brown, 1978). Flavell (1979) explain three type of metacognitive knowledge, Awareness of knowledge, Awareness of thinking, Awareness of thinking strategies. Flavell (1979) state that metacognition refer to the awareness of thought process : What we think, how we think and how we accomplish a certain task. Ability of monitor and evaluation is also included in metacognition. Metacognition is a series of thought that comes in one's mind when he engages in different task or situation. Biryukov (2003) and Hacker (1998) suggest that metacognition is an assumption of a one's thinking about his thinking which include metacognitive knowledge and metacognitive skills and metacognitive experience. Graphic Organizer is very effective tool for enhancing and promoting meaningful learning. The research article provide an evidence for improve the result of students achievements. Graphic organizer is a visual frame used to represent information and content in organize manner. It helps students to sort out and expend thinking skill and thought process. Graphic Organizer are diagrammatic, illustration used to organize and highlighting key content information and vocabulary (Lovitt, 1994). Graphic organizer visually demonstrate relationship between facts and concepts. With the help of graphic organizer students categorize and organize their thought process. It includes mapping, webbing, mind mapping etc. Graphic organizer is very useful for junior and elementary school level.

Title of study "Using Graphic organizer to develop Metacognitive Awareness in mathematics class room of elementary school students"**Objectives**

- To study the effectiveness of Graphic organizer metacognitive strategy on metacognitive awareness of elementary School Students.
- To study the difference between metacognitive awareness of eight grade students taught through Graphic organizer metacognitive strategy and convictional method.
- To develop graphic organizer metacognitive strategy module in mathematics.

Hypothesis

- There is no significant difference between pre-test and post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy.
- There is no significant difference between post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy and convictional method.
- There is no significant difference between boys' and girls' metacognitive awareness of elementary school students.

Design of Study

Researcher selected experimental pre-test, post-test, two group design for present study. First one is experimental group and second is controlled group. Experimental group taught through the Graphic Organizer Metacognitive Strategy method and the Controlled group taught through the Convictional Method. All 8th grade students of government school of Raipur block of Dehradun district in Uttarakhand taken as population of present study. Total



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52 students are the sample of present study which is selected by random method. Students divide in two group consisting of 26 students in one group.

Variables

In present study Graphic organizer metacognitive strategy module of mathematics teaching is independent variable, metacognitive awareness was considered as in depended variable. The variables manipulated to find out the effect imposed by it on metacognitive awareness of students.

Tool used for study

The first tool was **Graphic organizer metacognitive Instructional module** in mathematics developed by researcher using for present study. Graphic organizer metacognitive strategy on selected from class 8th mathematic CBSE Uttarakhand government text book. Second tool was **Metacognitive awareness scale** developed by researcher; it consists 30 items. The reliability of metacognitive awareness scale is 0.80 measured by "Cronch Breatch Alfa Method".

Limitation of the study

Study limited to the study of Metacognitive awareness of elementary students. Study is limited to the effect of Graphic organizer metacognitive strategy on metacognitive awareness of eight grade students.

Analysis and Interpretation of Data

H1-There is no significant difference between pre-test and post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy.

The table shows that mean post-test score of experimental group is more than mean pre-test score. SD of pre-test is 13.26 and post- test is 17.02 in experimental group. Calculated t-value is 3.282 it is significant at 1% level of significance. The difference between two means is found significant at 1% level. Hence the null hypothesis is rejected. There is significant difference between pre-test and post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy.

H2- There is no significant difference between post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy and traditional method.

The result from the above data indicates that, mean score of experimental group is 93.65 and control group is 78.51, the t-value is 0.3.65. Value of t- ratio is significant at 0.01 level of significant. Hence the hypothesis is rejected. There is significant difference between post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy and traditional method.

Effect size of Experimental group and control group.

The effect size of experimental group is 1.2, which shows huge effect in Cohen's d remarks. The effect size of control group is 0.05, which shows small effect in Cohen's d remarks. Effect size is maximum in experimental group comparison to control group. It shows positive effect of metacognitive awareness in experimental group.

H3- There is no significant difference between boys and girls metacognitive awareness of elementary school student's taught through Graphic organizer metacognitive strategy.

The result of the table indicates that, in experimental group, the metacognitive mean score of boys is 89.42 and metacognitive mean score of girls is 89.41. The calculated t-value was 0.0021 Value of t-ratio was not significant at 0.01 level of significant. Hence the hypothesis is accepted. There is no significant difference between boys and girls metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy.





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Findings of study

The finding of present study demonstrated that: Graphic organizer metacognitive strategy significantly effective in enhancing the achievement in mathematics of elementary school students. Graphic organizer metacognitive strategy is better learning strategy in mathematics comparative to convictional method. There is no significant difference between boys and girls' achievement in mathematics while taught through GO strategy. The t-value of pre-test post-test score of metacognition is significant at 0.01 level($t= 3.28$; $p>2.78$). There is significant difference between pre-test and post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy. The t-value of pre-test post-test score of metacognition is significant at 0.01 level($t= 3.65$; $p>2.78$). There is significant difference between post-test score of metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy and traditional method. There is no significant difference between boys' and girls' metacognitive awareness of elementary school students taught through Graphic organizer metacognitive strategy.

CONCLUSION

The result of study reveals that GO metacognitive strategy enhance class 8th students' metacognitive awareness in mathematics classroom. Research shows that GO strategy develop the understanding of different mathematical concept comparison to convictional method. It is evident that students' academic progress is greatly enhanced by cognitive and metacognitive methods. It is advised that curriculum in schools and other educational institutions prioritise both cognitive and metacognitive processes concurrently.

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Table 1- Comparison between experimental and control group in metacognitive awareness in pre-test score and post-test score

Group	No	Mean		SD		T value	Value of t –ratio at 1% level	Remarks At 1% level
		Pre-test	Post-test	Pre-test	Post-test			
Experimental Group	26	79.30	93.65	13.26	17.02	3.28	2.78	S





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Table 2: Comparison between experimental and control group in metacognitive awareness in post-test score

Group	Number	Mean	SD	t-value	t-value at 1% level	Remarks at 5% level
Experimental Group	26	93.65	17.02	3.65	2.78	S
Control Group	27	78.51	12.95			

Table 3-Effect size comparison between Experimental group and control group in metacognitive awareness.

Group	N	Mean		SD		Effect- d	Cohen's d remarks in effect size
		Pre	Post	Pre	Post		
Experimental Group	26	79.30	93.65	13.26	17.02	1.2	Huge
Control Group	27	78.44	78.51	12.44	12.95	0.05	Small

Table 4- Comparison between Boys and Girls metacognitive awareness in post-test score of experimental group.

Gender	Number	Mean	SD	t-value	t-value at 5% level	Remarks at 5% level
Boys	14	89.42	10.08	0.0021	2.78	NS
Girls	12	89.41	18.71			





Optimized Deep Learning - based Electrical Fault Detection in Power Transmission Grids

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ABSTRACT

Early and accurate fault detection in electrical power grids is a very essential research area because of its positive influence on network stability and customer satisfaction. In the past decades, many machine learning-based electrical fault detection systems have been developed. Though such systems automatically find a variety of electrical faults in the power grids, those algorithms are ineffective for large-scale electrical fault databases, which contain more voltage measurements or features. Hence, this article proposes a deep learning-based electrical fault detection system to recognize faults in the electrical power grids and transmission lines. It comprises data collection, preprocessing, and classification. First, the electrical signal transmitted through the electrical power grids or transmission lines is collected. Then, the preprocessing phase performs noise removal and signal decomposition to remove noisy signals and split the voltage capacities of all signals into smaller chunks, respectively. After that, different features are extracted, and the most relevant features are chosen by an Artificial Algae Algorithm (AAA), which also chooses the optimal hyperparameters of the classifier. Moreover, a Deep Neural Network (DNN) classifier is adopted to learn the selected features and recognize electrical faults. Finally, the experimental results show that the proposed system achieves better performance compared to the machine learning-based fault detection systems.

Keywords: Electrical power grids, Machine learning, PSO, Artificial algae algorithm, DNN, Hyperparameters





INTRODUCTION

Electrical energy systems are expanding quickly in both scale and scope worldwide. This expansion affects the whole power distribution business, from production to transmission lines. Unexpected voltage failures across transmission lines are one of the common issues faced by the power grid [1-2]. An abrupt shift in both voltage and current values, or greater levels of voltage and current than those that are typically anticipated to occur in steady state conditions, is considered an electrical or electromagnetic fault [3]. Human fault, external factors, and system malfunctions are also responsible for this voltage and current divergence from their optimum levels [4]. Additionally, if an electromagnetic fault happens, an overly high power is forced to travel across the network, which might harm machines and devices [5]. Thus, it is essential to identify faults as soon as possible to avoid component failure, disruption of operations, and destruction of global biodiversity [6]. It was claimed that there is a study gap in this area, such as the automation and evaluation of the method, despite the fact that electromagnetic fault detection methods based on binary categorization were the subject of substantial study over the last century [7]. Therefore, an intelligent system that performs effectively in the power grids of the actual world is desperately needed. A specific type of detection techniques known as outlier detection in machine learning aims to find aberrant observations or occurrences in a database [8]. Anomalies, also known as outliers, are essentially observations that deviate significantly from the predicted structure of a database and are intrinsically unusual related to the greater part (regular) of observations. Similarly, electromagnetic faults happen in real-life transmission lines infrequently (below 5%), whereas the remaining impulses are normal [9]. As a result, using anomaly detection will be more appropriate for solving the electrical fault detection problem than using the more traditional binary classification, where there must be a sufficient number of flawed signals in the dataset to prevent the binary classifier from favoring the normal class [10].

The models for anomaly-based detection are trained only on normal samples to identify the typical behavior of data. Then, they can find any hidden information that differs from the behavior that has been maintained [11]. Despite the development of several electrical fault detection approaches over the past 10 years, effective and reliable fault detection systems are still difficult to find in practical applications. Additionally, the significant scarcity of substantial quality for system validation is one of the major obstacles that slow down development in this direction. So, a novel anomaly-based electrical fault detection system is developed that is compatible with the concept of faults in electrical power grids [12]. Data preprocessing and pretraining, the two processes that come before the training phase, are advantageous. The pretraining phase uses a Particle Swarm Optimization (PSO)-based approach to choose the model's ideal hyperparameters, while the data preparation phase performs all basic operations on the raw data. Principal Component Analysis (PCA) and One-Class Support Vector Machines (OC-SVMs) are also employed to find abnormalities. On the other hand, the PCA and OC-SVMs take more time for large-scale electrical fault databases. Also, the PSO has poor exploration and a low convergence rate in the iterative process for parameter selection. To combat these issues, a new optimization algorithm and deep learning classification model are required to automatically detect electrical faults from the large-scale database. Hence, this article proposes a deep learning-based electrical fault detection system to recognize faults in the electrical power grids and transmission lines. It comprises data collection, preprocessing, and classification. Initially, the electrical signal transmitted through the electrical power grids or transmission lines is collected. Then, the preprocessing phase performs noise removal and signal decomposition to remove noisy signals and split the voltage capacities of all signals into smaller chunks, respectively. After that, different features are extracted, and the most relevant features are chosen by an AAA, which also chooses the optimal hyperparameters of the classifier. Moreover, the DNN classifier is adopted to learn the selected features and recognize electrical faults. Thus, the accuracy of detecting electrical faults in power grids or transmission lines is increased significantly.

LITERATURE SURVEY

Zhang et al. [13] developed a novel transformer fault diagnosis method using an Internet of Things (IoT) based monitoring system and an Ensemble Machine Learning (EML). First, transformer vibration signals were measured by



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using the data measurement subsystem, and they were sent to the remote server by using the data reception subsystem. Then, an EML composed of Deep Belief Networks (DBNs) and Stacked Denoising Auto encoders (SDAs) with different activation functions, and Relevance Vector Machines (RVMs) was proposed. DBNs and SDAs were used to extract features from the signals, and RVMs were respectively employed as classifier. To ensure efficient of the EML, a novel combination strategy was proposed. Gangwar et al. [14] presented K-means clustering and weighted K-Nearest Neighbor (KNN) Regression based algorithm for the protection of transmission line. The three-phase current signals of both the terminals were synchronized and sampled with sampling frequency of 3.84 kHz. Cumulative Differential Sum (CDS) was computed by subtracting the samples of current cycle from the previous cycle at both the terminals of transmission line. K-means clustering was applied on CDS to compute two centroids using moving window of width, equal to one cycle. Difference between the absolute values of centroids was computed at both the terminals and represented by Centroid Difference (CD). The CD of both the terminals were added to compute the fault Index. The computed fault index was used to detect and classify the types of faults. The location of the fault was estimated by the weighted K-NN regression method. Rohani & Koochaki [15] developed a new hybrid system based on Adaptive Neuro-Fuzzy Inference System (ANFIS) with optimal parameters and Hilbert-Huang (HH) transform for fault location in Voltage Sourced Converter-HVDC (VSC-HVDC) systems. At first, HH transform was applied to extract new features from current signal. After that, ANFIS uses the extracted features to estimate the fault location in transmission lines. Learning algorithm determines the accuracy and efficiency of each machine-learning algorithm. Also, enhanced Chaotic Dynamic Weight Particle Swarm Optimization (CDWPSO) algorithm was used as learning algorithm to train the ANFIS.

Lu et al. [16] developed a new approach based on the Improved Empirical Wavelet Transform (IEWT) and Salp Swarm Algorithm (SSA) optimized Kernel Extreme Learning Machine (KELM). First, IEWT is used to adaptively decompose the vibration signal to obtain a set of Empirical Wavelet Functions (EWFs). Then, the first n-order components with high correlation coefficient are collected. The mean value, variance, kurtosis, Refine Composite Multi-Scale Entropy (RCMSE), and Time-Frequency Entropy (TFE) of these n-order components were calculated to construct a fusion feature vector. Finally, a two-level diagnostic model based on SSA-KELM is established. The first-level of it was applied to identify normal and abnormal states, and the second-level was selected to identify fault categories in the abnormal states. The proposed method can effectively diagnose the existing fault categories in the training set and accurately identify the unknown categories of faults. Li et al. [17] developed a new fault detection and classification method for microgrids. Hilbert-Huang Transform and sliding window strategy were used in fault characteristic extraction. The instantaneous phase difference of current high-frequency component was obtained as the fault characteristic. A self-adaptive threshold was set to increase the detection sensitivity. A fault can be detected by comparing the fault characteristic and the threshold. Furthermore, the fault type was identified by the utilization of zero-sequence current. Baloch & Muhammad [18] presented the Hilbert transform and data mining approach to protect the microgrid. At first, the Hilbert transform was used to preprocess the faulted voltage and current signals to extract the sensitive fault features. Then, the obtained dataset of the extracted features was input to the logistic regression classifier for fault detection. Furthermore, fault classification was done by training the AdaBoost classifier.

Harish et al. [19] presented detecting and classifying faults in transmission lines for wide-area backup protection using Phasor Measurement Units (PMU) data. The faults were detected and classified using a Weighted Extreme Learning Machine (WELM) algorithm, which considers the variable distribution of data among the different classes using a weighted approach. The PMU signal data used were generated, and the input features data were derived using a wavelet transform-based ensemble feature extraction technique. Moreover, the WELM classifier was optimized using Particle Swarm Optimization (PSO). Al Kharusi et al. [20] presented a comprehensive machine-learning-based approach for detecting and classifying faults in transmission lines connected to inverter-based generators. A two-layer classification approach was considered: fault detection and fault type classification. The faults were comprised of different types at several line locations and variable fault impedance. The features from instantaneous three-phase current and voltages and calculated Swing-Center Voltage (SCV) were extracted in time, frequency, and time-frequency domains. The unbalanced data problem was investigated and mitigated using the



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Synthetic Minority Class Oversampling Technique (SMOTE). The hyperparameters of the classifiers, namely decision trees, SVM, KNN, and Ensemble trees were optimized using the Bayesian optimization algorithm.

MATERIALS AND METHODS

This section explains the proposed electrical fault detection system briefly. Figure 1 shows the block diagram of the presented study. The proposed system seeks to recognize anomalous patterns in the electrical power line's voltage signals. Since anomaly-based detection models cannot deal with an electrical signal in its raw form, the input signal has to undergo a preprocessing phase where voltage measurements of the signal are filtered from noise and decomposed into chunks. Afterward, a feature extraction process is executed to characterize the pattern of voltage measurements, and then these features are put into a data record and normalized. These records of the input signals are given to the AAA-based algorithm to choose the optimal features and hyperparameters used in the classifier models. The selected features are used to train the deep learning classifier, and the trained model is applied to detect any faulty signals from the normal signals.

Database Description

The VSB (Technical University of Ostrava) database is a modern database that was published online in 2018 on the Kaggle Competition website. In addition to that, it is a realistic fault detection database because it was created by the ENET Center at the Technical University of Ostrava using a new device for capturing electrical signals passed through real power lines. Regarding the structure of the VSB database, it has 8712 samples, and each sample is merely an electrical signal that has 800,000 voltage measurements stored as integer values. These signals are captured from a real 3-phase electrical power grid that operates at 50 Hz, and all signals are recorded over a single complete grid cycle (20 milliseconds). Additionally, there is a feature, named Class, in the VSB database that determines the type of each signal, i.e., normal and faulty classes are labeled as 0 and 1, respectively. On the other hand, the majority of samples in the VSB database belong to normal signals (8187 samples), while the rest (525 samples) are faulty signals. This severe defect between the number of normal and faulty samples in the VSB database may lead to poor classification results because the classifiers will bias toward the majority class (normal). Hence, employing anomaly-based detection models is inevitable with such an imbalanced database.

Data Preprocessing and Feature Extraction

This phase performs all fundamental operations on the samples of the VSB database. It is very vital because it prepares data for modeling and analyzing by the used anomaly-based fault detection models. This phase comprises different processes, including signal denoising, signal decomposition, feature extraction, data normalization, and feature selection.

Signal Denoising

Each signal in the VSB database is filtered from noise separately, as follows: Initially, a copy of all voltage measurements of particular signal is saved and ordered in an ascending order. Then, the first quartile Q_1 (25% percentile) and the third quartile Q_3 (75% percentile) of the signal measurements are calculated. The value of IQR (the middle 50% of the signal) is computed as:

$$IQR = Q_3 - Q_1 \quad (1)$$

After that, the value of IQR is multiplied by k value which is an adjustment factor. The aim of using such a factor is to determine the strength of outliers. Two widely used values of k are 1.5 and 3. The value of 1.5 is used to identify weak (minor) outliers, the value of 3 is used to determine strong (major) outliers in data. In the electrical fault detection problem, two types of outliers are familiar: fault measurements which slightly deviate from the normal values and noise measurements which extremely differ from the normal values. Therefore, the fault measurements have to be kept to accomplish the fault detection task, whereas the noise measurements have to be removed. Accordingly, k value is set to be 3.





Signal Decomposition

After signal denoising process is completed, the remaining voltage measurements of the i^{th} signal in the VSB database are equal to $(800000 - l)$, where l is the number of voltage measurements in the i^{th} signal that are identified as a noise and removed. Signal decomposition is the process of partitioning the remaining voltage measurements of each signal into smaller chunks that are easier to detect faults within them. In this study, all signals in the VSB database are decomposed into 2 chunks. Let M denote the number of chunks; then, the signal decomposition process breaks up the remaining voltage measurements of each signal in the VSB database into M chunks, as follows:

$$Chunk_size = Round\left(\frac{\text{remaining measurements of signal}_i}{M}\right) \quad (2)$$

$$Chunk_j^i = X_{[(j-1)*Chunk_size]+1}^i, \dots, X_{[(j-1)*Chunk_size]+Chunk_size}^i, j = 1, \dots, M \quad (3)$$

In Eqns. (2) & (3), $Chunk_size$ is the size of the chunk, $Round$ is a function that rounds a number to an integer value, X_d^i is the d^{th} voltage measurements of the i^{th} signal and $Chunk_j^i$ is the j^{th} chunk of the i^{th} signal.

Feature Extraction

A feature extraction process is performed to reduce dimensions of the feature space. Thus, 19 features from the existing voltage measurements are extracted for each chunk of the signal separately. The extracted features are mean, standard deviation, max value, min value, percentile, relative percentile, lower bound, upper bound, and height (distance). The number of features in the reduced database is equal to $(19 * M) + 1$, where M is the number of chunks.

Artificial Algae Algorithm for Selection of Optimal Features and Hyperparameters

After extracting features from all chunks of the signal, all extracted features are given as input to the AAA for optimal feature selection. The AAA is a novel bio-inspired strategy, which imitates the living habits and behaviors of microalgae. It is designed to update the major population by simulating microalgae habits like algae inclination, regeneration and adjustment to the atmosphere. So, algae possess 3 primary operations: progression, helical motion and adjustment. This algorithm's population is made up of algae colonies. When the algae individual in an algae colony gets adequate sunlight, the algal colony can develop to a larger volume. But, because of inadequate sunlight, the algae colony doesn't expand sufficiently during the progression period. All algae colonies can migrate towards the strongest algae colony in a helical motion. The major operations in the AAA are described below.

Consider $a_i = (a_{i1}, a_{i2}, \dots, a_{ix})$, where $i = 1, 2, \dots, n$ and a_i is the solution in the hunt space. The algae population (AP) is defined as:

$$AP = \begin{bmatrix} a_{11} & a_{21} & \dots & a_{1x} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nx} \end{bmatrix} \quad (4)$$

Consider the algae colony dimension i^{th} algae colony is S_i and the fitness function is $f(a_i)$ and S_i can be updated by

$$S_i = dimension(a_i) \quad (5)$$

$$\rho_i = \frac{S_i + 4f(a_i)}{S_i + 2f(a_i)} \quad (6)$$

$$S_i^{t+1} = \rho_i S_i^t \quad (7)$$

In Eqns. (5) – (7), ρ_i is the update coefficient of S_i and t is the current population.

Helical Motion Step: The algae colony migrates in 3D so that the motion of the algae colony in 3D is defined by

$$A_{ih}^{t+1} = A_{ih}^t + (A_{jh}^t - A_{ih}^t)(sf - \tau_i)q \quad (8)$$

$$A_{ik}^{t+1} = A_{ik}^t + (A_{jk}^t - A_{ik}^t)(sf - \tau_i)\cos\alpha \quad (9)$$

$$A_{il}^{t+1} = A_{il}^t + (A_{jl}^t - A_{il}^t)(sf - \tau_i)\sin\beta \quad (10)$$

Eq. (8) defines the motion in the 1D (refer to x), whereas Eqns. (9) and (10) define the motion in the 2D (refer to y, z), k, h and l are random values regularly created from 1 to d , A_{ih}, A_{ik}, A_{il} simulate x, y and z coordinates of i^{th} algae colony, j is the index of an adjacent algae colony, q refers to an independent random value in $(-1, 1)$, α and β denote random degrees between 0 and 2π , sf represents the shear force and τ_i is the friction surface region of i^{th} algae colony, which is determined as:





$$\tau_i = 2 \ni \pi r_i^2 \quad (11)$$

$$r_i = \left(\frac{3 S_i}{4\pi} \right) \quad (12)$$

In Eqns. (11) and (12), r_i is the radius of the hemisphere of i^{th} algae colony and S_i is its dimension.

Progression Step

In AAA, the algae colony A_i becomes larger if it migrates toward the best location to achieve the possible solutions. This procedure is defined as follows:

$$Largest = \operatorname{argmax}\{\operatorname{dimension}(A_i)\}, i = 1, \dots, n \quad (13)$$

$$Smallest = \operatorname{argmin}\{\operatorname{dimension}(A_i)\}, i = 1, \dots, n \quad (14)$$

$$Smallest_j = Largest_j, j = 1, \dots, d \quad (15)$$

In Eqns. (13) – (15), *Largest* and *Smallest* define the largest and smallest algal colony, j is the random value that defines the index of the particular algae individual arbitrarily and d is the problem dimension.

Adjustment Step: The algae colony that is not expanding adequately can grow itself to its background. After the motion, the fitness value is represented as either low or high. Once algae colony motion is finished, the algae colony with the maximum starvation value (as in Eq. (16)) grows itself to the largest algae colony with adjustment probability A_p .

$$A_s = \operatorname{argmax}\{\operatorname{starvation}(A_i)\}, i = 1, \dots, n \quad (16)$$

In Eq. (16), $\operatorname{starvation}(A_i)$ is utilized to determine the starvation level of algae colony A_i . The adjustment step of AAA of the algae colony procedure is represented as:

$$A_{sj}^{t+1} = \begin{cases} A_{sj}^t + (Largest_j - A_{sj}^t) \cdot rand_1, & \text{if } rand_2 < A_p, j = 1, \dots, d \\ A_{sj}^t, & \text{or else} \end{cases} \quad (17)$$

In Eq. (17), s denotes the index of the algae colony with the maximum starvation value and j represents the index of algae individual, $rand_1$ and $rand_2$ are random values from 0 to 1, and A_p refers to the adjustment probability from 0.3 to 0.7.

Algorithm for AAA for Feature/Hyperparameter Selection

Input: Extracted features (or hyperparameters of deep learning classifier)

Output: Most relevant features (or optimal hyperparameters)

1. Create an initial generation of n algae colonies with arbitrary solutions;
2. Determine fitness value $f(a_i), i = 1, \dots, n$;
3. **while**(termination criteria not achieved)
4. **for**($i = 1:n$)
5. **while**(energy of i^{th} colony not finished)
6. Update the colony with helical motion;
7. **end while**
8. **end for**
9. Perform progression process;
10. Perform adjustment process;
11. **end while**

Deep Learning-based Classifier for Electrical Fault Detection

Further, the selected most relevant features are fed to the DNN classifier to detect the normal and faulty signals. The DNN consists of an input layer, hidden layers and an output layer (as portrayed in Figure 2) to recognize the faulty signals. If the input feature x_i is given to the DNN, the output of the hidden layer is defined as the tan-sigmoid transfer function:





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$$f(x_i) = \frac{2}{1+e^{-2x_i}} - 1 \quad (18)$$

Each input feature has its weight values as w_1, w_2, \dots, w_n and the weighted sum of the inputs is done by the adder function as:

$$u = \sum_{i=1}^n w_i x_i \quad (19)$$

The output layer of DNN is defined via the following formula:

$$y = f(\sum_{i=1}^n w_i x_i + b_i) \quad (20)$$

In Eq. (20), y is the output neuron value; $f(\cdot)$ is the transfer function, w_i refers to the weight values, x_i denotes input features and b_i refers to the bias value. According to the output neuron values, the given features are learned and classified into normal and faulty signals. Table 1 presents the hyperparameters of the DNN classifier.

EXPERIMENTAL RESULTS

In this section, the efficiency of the presented AAA-DNN system for electrical fault detection is assessed by implementing it in Python 3.12. In this experiment, the VSB database is used, which is briefly described in Section 3.1. From this database, 70% of voltage measurements are used for training and the remaining 30% is used for testing. Also, by implementing existing classifier models such as PSO-OC-SVM [12], RVM [13], CDWPSO-ANFIS [15], SSA-KELM [16], and PSO-WELM [19] on the considered VSB database, a comparative study is presented to understand the detection performance in terms of accuracy, precision, recall and f-measure.

- Accuracy: It is the proportion of exact detection over the total samples tested.

$$Accuracy = \frac{True\ Positive\ (TP) + True\ Negative\ (TN)}{TP + TN + False\ Positive\ (FP) + False\ Negative\ (FN)} \quad (21)$$

In Eq. (21), the number of positive (normal signals) correctly detected as positive, while the number of negative (fault signals) correctly detected as negative is TN. Likewise, FP is the number of normal signals incorrectly detected as fault signals, whereas FN is the number of fault signals incorrectly detected as normal.

- Precision: It determines the correctly detected samples at TP and FP rates.

$$Precision = \frac{TP}{TP + FP} \quad (22)$$

- Recall: It is the proportion of samples, which are correctly detected at TP and FN rates.

$$Recall = \frac{TP}{TP + FN} \quad (23)$$

- F-score (F): It is the harmonic mean of precision and recall.

$$F = \frac{2 \times Precision \times Recall}{Precision + Recall} \quad (24)$$

From the analyses presented in Figure 3, it is indicated that the AAA-DNN algorithm on the VSB database achieves a better efficiency compared to the other algorithms for detecting the electrical faults. The precision of the AAA-DNN classifier is 61.82%, 34.13%, 24.27%, 10.69%, and 6.83% higher than the RVM, PSO-WELM, CDWPSO-ANFIS, SSA-KELM, and PSO-OC-SVM classifiers, respectively. The recall of the AAA-DNN is 79.38% greater than the RVM, 57.84% greater than the PSO-WELM, 44.47% greater than the CDWPSO-ANFIS, 28.17% greater than the SSA-KELM, and 14.64% greater than the PSO-OC-SVM. Also, the f-measure of the AAA-DNN classifier is 68.64%, 47.55%, 27.97%, 19.67%, and 10.72% higher than the RVM, PSO-WELM, CDWPSO-ANFIS, SSA-KELM, and PSO-OC-SVM classifiers, respectively. Furthermore, the accuracy of the AAA-DNN is 40.95% better than the RVM, 27.86% better than the PSO-WELM, 15.97% better than the CDWPSO-ANFIS, 9.31% better than the SSA-KELM, and 2.92% better than the PSO-OC-SVM for electrical fault detection.





CONCLUSION

In this study, a deep learning-based electrical fault detection system was developed for detecting electrical faults in the power transmission grids. At first, the VSB electrical signal fault database was acquired and preprocessed by different methods to remove noisy signals, partition each signal into smaller chunks, and extract features. From the extracted features, the most relevant features were chosen by the AAA, which was also used for choosing the optimal hyperparameters of the DNN. Moreover, the DNN classifier was initialized by the optimal hyperparameters and trained by the selected features. The trained DNN was later used for recognizing electrical faults. At last, the experimental results show that the AAA-DNN-based electrical fault detection system has a 90.28% accuracy compared to the other machine learning algorithms.

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Table 1. DNN Hyperparameters

Parameters	Values
Input layer neurons	4
First hidden layer neurons	50
Second hidden layer neurons	50
Third hidden layer neurons	20
Output layer neurons	1
Learning rate	0.001
Transfer function	Tan-Sigmoid
Maximum number of iterations	100

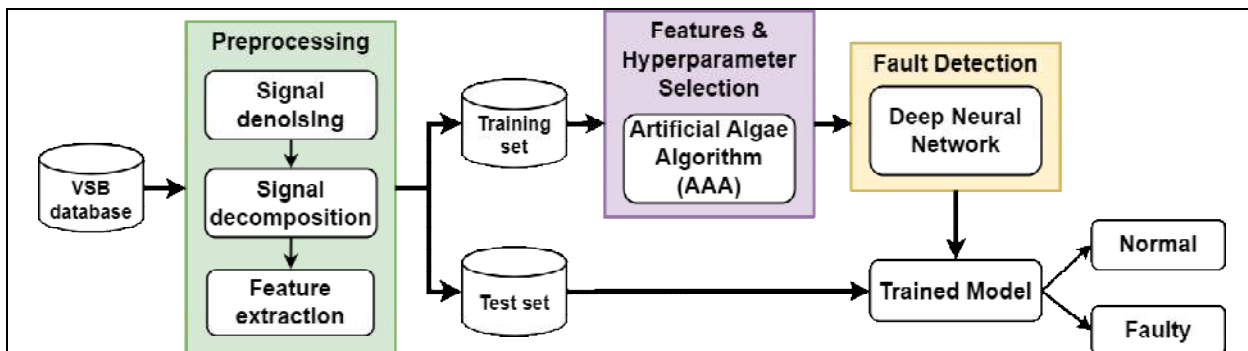


Figure 1. Block Diagram of Proposed Electrical Fault Detection System

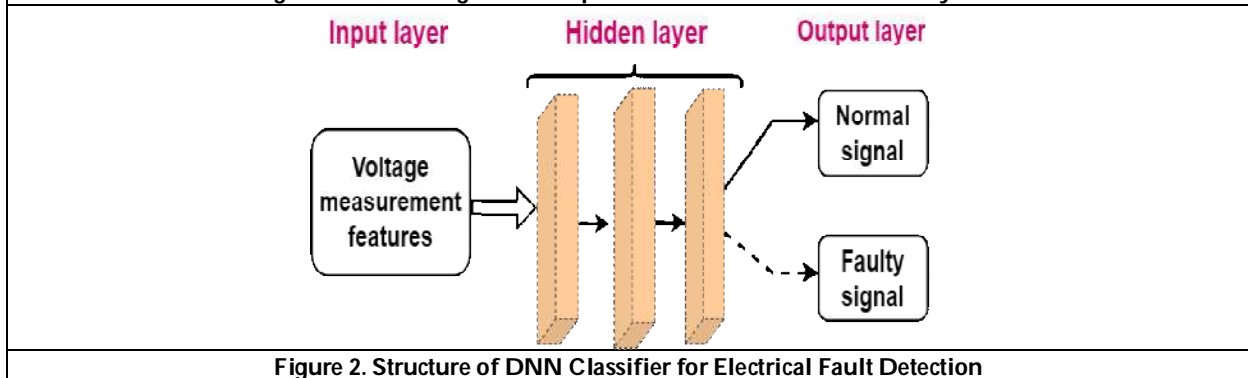


Figure 2. Structure of DNN Classifier for Electrical Fault Detection





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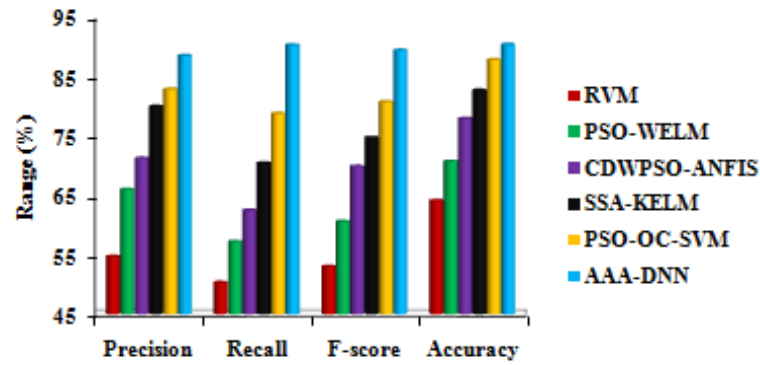


Figure 3. Comparison of Different Electrical Fault Detection Systems





Application of Intuitionistic Fuzzy Multi-Objective Linear Programming of Fuzzy Optimization Techniques in Agriculture

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ABSTRACT

The characteristics of contemporary agriculture include a multitude of conflicting optimization criteria that make it difficult to make decisions when planning agricultural output. The study presented in this paper examines the application of intuitionistic fuzzy optimization technique to the problem of agricultural output planning, with a focus on smallholder farmers in Sikkim and hills of West Bengal and North-Eastern (NE) States. In most cases, linear programming is used to formulate the crop planning problem. However, in practical agricultural production planning situations, there are a lot of unknown variables; therefore crop future revenues are approximate and uncertain. Consequently, we suggest a crop planning model that makes use of intuitionistic fuzzy optimization. This study aimed to find the optimal land allocation for wheat, corn, and oil in light of demand and water restrictions in order to maximize yield while balancing the opposing aims of cost reduction and profit maximization. While objectives and other limitations are perceived as hazy, only the constraint linked to resource availability is regarded as unambiguous. Since objectives and other limitations are perceived as hazardous, only the constraint linked to land allocation is regarded as clear. The intuitionistic fuzzy Multi-objective linear programming technique has been observed to be effective in handling many objectives in a fuzzy, unclear context.

Keywords: Intuitionistic Fuzzy set, Optimization, Crop Planning problem.

Mathematics Subject Classification (MSC2020): 03F55, 03E72.





INTRODUCTION

A common goal of agricultural production planning problems is not just profit optimization with cost minimization; a realistic crop production planning problem includes multiple objectives such as input resource optimization, such as man hours, machine hours, fertilizers, water requirements, and many more. One of the main goals of agricultural production planning problems is to maximize the profit under minimum investment with limited land. These aims are also inherently conflicting. Furthermore, because they depend on a variety of uncontrollable factors, the price and cost of growing food grains are subject to natural fluctuations. As a result, these limitations are ambiguous, imprecise, and unpredictable. These characteristics of crop production issues make the conventional multi-objective approaches unsuitable for creating cropping models. In order to study fuzzy programming and linear programming with many goals, [1] originally employed the fuzzy set idea provided by [2]. While [3] expanded the idea of fuzzy sets to include intuitionistic fuzzy sets, [4] investigated optimization in an intuitionistic fuzzy setting [5] et al. The linear programming technique in fuzzy sets that are intuitionistic was developed by [5]. [6] have conducted a recent study on multi-objective linear programming issues within intuitionistic fuzzy environments. Agriculture is one of India's most significant economic industries. Seventy-seven percent of Indians live in rural areas, and three-quarters of these people rely on agriculture and related industries for a living. Despite contributing to just fifteen per cent economic of the gross domestic product of India, the agriculture industry produces 55% of the workforce and is the largest source of labor in the country. With rain feeding accounting for about 87 millimetres per hectare and approximately 61% of net cultivated land, the monsoon season is crucial to Indian agriculture's ability to predict whether a given year's crop will be abundant, average, or bad. Bihar is located in the Ganga River Basin's lowlands. It has an abundance of water resources, particularly groundwater resources, and fertile alluvial soil. Bihar's agriculture is therefore rich and varied. Bihar produces pulses such as arhar, urad, moong, gram, pea, lentils, and khesaria. Bihar is a big guava fruit, banana, and mango crop. Bihar's other major agricultural products are cotton and sugarcane [7]. The use of mathematics to quantitatively answer different problems in the economic and management domains is becoming more and more popular as issues with agriculture and economic management arise recently [8,9]. The most important of these is the correct construction of economic mathematical models associated with these issues.

The creation of the mathematical model is a necessary first step in using mathematics to solve agricultural economic and management issues, and it continues throughout the problem-solving process. The application of generalized fuzzy linear programming to Sikkim and hills of West Bengal and N.E. States, agricultural management challenges demonstrate that it is quite successful in dealing with the problem of permitting unclear information to surface in the procedure of optimization and results. However, it is unable to address the issue of uncertain random variables in a non-fuzzy space or to take the financial penalty for policy violations. The top priority for policymakers is economic punishment. The most advantageous course of action is to "punish" the minor ones, edit them, and make the second option after the random occurrence in the second stage occurs in order to make the objective function instantly. In order to achieve this, if there are no constraints, linear constraints must be established first. If not, the fuzzy linear gauge will become a generalized fuzzy linear programming, which will lead to a vague and confusing objective analysis. Additionally, the inability to establish the corresponding mathematical model will prevent the problem from being solved. We suggest employing an enhanced fuzzy linear programming model to handle agricultural economic management challenges. Specifically, we aim to address the issue of random variables resulting from uncertainty and offer recommendations for Sikkim and the hills of West Bengal and N.E. States. Agricultural economic management to enhance its planting structure. Ultimately, the increased output value of agricultural production will foster the growth of local agriculture. In this study, a class of multi-objective fuzzy linear programming problems with elastic constraints is constructed and discussed, i.e., a class of multi-objective fuzzy linear programming problems with full fuzzy coefficients except for the coefficients of the elastic constraint condition. Fuzzy structural element analysis provides the best answer, which is then used in agricultural economic management. The work begins with an introduction to key terminology and definitions. Next, we discuss fuzzy optimization techniques, intuitionistic fuzzy optimization techniques, crop production planning problems, and mathematical formulations of the problems. Finally, we present the research findings.





Mathematical Model

Multi objective linear programming problem

A multi-objective optimization problem with n choice factors, q constraints, and p objectives can be generalized as follows:

$$\begin{aligned} &\text{Max } \{f_1, f_2, \dots, f_p\} \\ &\text{Such that} \\ &g_j(X) \leq 0, \quad j = 1, 2, \dots, q \\ &X = \{x_1, x_2, \dots, x_n\}, \\ &x_i \geq 0, i = 1, 2, \dots, n \end{aligned} \quad (1)$$

Complete solution

If there exists $x^0 \in X$ such that $f_k(x^0) \leq f_k(x)$ for any $x \in X$, then x^0 is considered a complete optimal solution for issue (1). However, generally speaking, no truly optimal solution exists that simultaneously maximizes all multiple-objective functions, especially when the goal functions are intrinsically conflicting. Therefore, instead of using a completely optimal solution in multi-objective programming, Pareto optimality was presented as a solution idea.

Pareto-Optimality

$x^0 \in X$ is said to be a Pareto optimal solution for (1) if there does not exist another $x \in X$ such that $f_k(x^0) \leq f_k(x)$ for all $k = 1, 2, \dots, p$ and $f_j(x^0) < f_j(x)$ for at least one $j = 1, 2, \dots, p$.

Linear fractional programming approach

Let s be one of k objectives with a ratio that needs to be maximized. Limiting the number of objectives to two will make things simpler. The two linear objectives are $f_p(x) > 0$ and $f_q(x) > 0$, and their ratio will create a new objective function. This will result in linear fractional programming, which can be understood as

$$\text{Maximize } \frac{f_p(x)}{f_q(x)} \quad (2)$$

Intuitionistic fuzzy sets

An intuitionistic fuzzy set \tilde{A} assigns to each element x of the universe X a membership degree $\mu_{\tilde{A}}(x) \in [0, 1]$ and non-membership degree $\nu_{\tilde{A}}(x) \in [0, 1]$ such that $\mu_{\tilde{A}}(x) + \nu_{\tilde{A}}(x) \leq 1$. A IFS is mathematically represented as, $\{(x, \mu_{\tilde{A}}(x), \nu_{\tilde{A}}(x)) | x \in X\}$ where, $1 - \mu_{\tilde{A}}(x) - \nu_{\tilde{A}}(x)$ is called hesitancy margin.

Example

Let X be a member of group A , which consists of all the nations having elected governments. Let $M(x)$ represent the proportion of voters who supported the government and $N(x)$ represent the proportion who did not. In the case when $\mu_{\tilde{A}}(x) = \frac{M(x)}{100}$ and $\nu_{\tilde{A}}(x) = \frac{N(x)}{100}$ the degree of support is indicated by $\mu_{\tilde{A}}(x)$ the degree of opposition by $\nu_{\tilde{A}}(x)$ and the indeterminacy, or portion that casts invalid or poor votes, is represented by $h(\tilde{A}) = 1 - \mu_{\tilde{A}}(x) - \nu_{\tilde{A}}(x)$

Intuitionistic Fuzzy Number

An Intuitionistic Fuzzy Set (IFS) $\tilde{A} = (\mu_{\tilde{A}}, \nu_{\tilde{A}})$ of real numbers is said to be an intuitionistic fuzzy number if $\mu_{\tilde{A}}$ and $\nu_{\tilde{A}}$ are fuzzy numbers. Hence $\tilde{A} = (\mu_{\tilde{A}}, \nu_{\tilde{A}})$ denotes an intuitionistic fuzzy number if $\mu_{\tilde{A}}$ and $\nu_{\tilde{A}}$ are fuzzy numbers with $\nu_{\tilde{A}} \leq \mu_{\tilde{A}}$, where $\mu_{\tilde{A}}$ denotes the complement of $\mu_{\tilde{A}}$.

Some operations on intuitionistic fuzzy sets are:

$$\tilde{A} \cap \tilde{B} = \{(x, \min(\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)), \max(\nu_{\tilde{A}}(x), \nu_{\tilde{B}}(x))) | x \in X\}$$

$$\tilde{A} \cup \tilde{B} = \{(x, \max(\mu_{\tilde{A}}(x), \mu_{\tilde{B}}(x)), \min(\nu_{\tilde{A}}(x), \nu_{\tilde{B}}(x))) | x \in X\}$$

Intuitionistic Fuzzy optimization Technique

Consider the general optimization problem given as

$$\text{Max } f_i(x), \quad i = 1, 2, \dots, p$$





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Such that

$$g_j(x) \leq 0, \quad j = 1, 2, \dots, q \quad (3)$$

$$x \geq 0$$

Where X represents the decision variables, $tq_j(x)$ represents the constraint functions, $f_i(x)$ represents the objective functions, and p and q , respectively, represent the number of objectives and constraints. All restrictions must be precisely satisfied by the solution to this crisp model. Similar to the previous problem, the degree of acceptance of the constraints and objective(s) must be maximized in the fuzzy optimization model:

$$\widetilde{Min} f_i(x), i = 1, 2, \dots, p$$

Such that

$$g_j(x) \leq 0, j = 1, 2, q \quad (4)$$

$$x \geq 0$$

The notation \widetilde{Min} represents fuzzy minimization, while \leq indicates fuzzy inequality. In order to solve system (5), [10] and [2] employed fuzzy sets to maximize the degree of acceptance (or membership) of the aim and constraints.

$$\text{Max } \mu_k(x), k = 1, 2, \dots, p + q$$

Such that

$$0 \leq \mu_k(x) \leq 1, \quad (5)$$

$$x \geq 0$$

and the degree of satisfaction with the corresponding fuzzy sets is indicated by $\mu_k(x)$. Since the degree of non-membership in a fuzzy set is a complement to membership, minimizing the non-membership will automatically occur when the membership function is maximized. However, the degree of rejection and acceptance in an intuitionistic fuzzy set are determined simultaneously, and when these two degrees do not complement one another, IFS may provide a more generic tool for characterizing this uncertainty-based optimization model. Given (6), the Intuitionistic Fuzzy Optimization (IFO) model is as follows:

$$\text{max } \mu_k(x), k = 1, 2, \dots, p + q$$

$$\text{min } v_k(x), k = 1, 2, \dots, p + q$$

Such that

$$x \in X$$

$$v_k(x) \geq 0, k = 1, 2, \dots, p + q \quad (6)$$

$$\mu_k(x) \geq v_k(x), k = 1, 2, \dots, p + q$$

$$\mu_k(x) + v_k(x) \leq 1$$

$$k = 1, 2, \dots, p + q$$

$$\tilde{F} \cap \tilde{C} = \{(x, \min(\mu_{\tilde{F}}(x), \mu_{\tilde{C}}(x)), \max(v_{\tilde{F}}(x), v_{\tilde{C}}(x)))\} \quad (7)$$

Where \tilde{F} is integrated intuitionistic fuzzy objective and \tilde{C} denotes integrated intuitionistic fuzzy constraints and is defined as:

$$\tilde{F} = \{(x, \mu_{\tilde{F}}(x), v_{\tilde{F}}(x)) | x \in X\}$$

$$\bigcap_{i=1}^p \tilde{F} = \{(x, \min_{i=1}^p \mu_i^f(x), \max_{i=1}^p v_i^f(x)) | x \in X\},$$

$$\tilde{C} = \{(x, \mu_{\tilde{C}}(x), v_{\tilde{C}}(x)) | x \in X\}$$

$$\bigcap_{i=1}^q \tilde{C} = \{(x, \min_{j=1}^q \mu_j^g(x), \max_{j=1}^q v_j^g(x)) | x \in X\},$$

and the Intuitionistic Fuzzy Decision Set (IFDS) denoted as \overline{D} :

$$\overline{D} = \tilde{F} \cap \tilde{C} = \{(x, \mu_{\overline{D}}(x), v_{\overline{D}}(x)) | x \in X\}, \quad (8)$$

$$\mu_{\overline{D}}(x) = \min\{\mu_{\tilde{F}}(x), \mu_{\tilde{C}}(x)\} = \min_{k=1}^{p+q} \mu_k(x), \quad (9)$$

$$v_{\overline{D}}(x) = \max\{v_{\tilde{F}}(x), v_{\tilde{C}}(x)\} = \max_{k=1}^{p+q} v_k(x) \quad (10)$$

Where the degrees of acceptance and rejection of IFDS are indicated by $\mu_{\overline{D}}(x)$ and $v_{\overline{D}}(x)$ respectively. Moreover, for a viable solution, the acceptance degree of IFDS is consistently less than or equal to the acceptance of any goal and constraint, and the rejection degree of IFDS is consistently greater than or equal to the rejection of any objective and constraint. So,

$$\mu_{\overline{D}}(x) \leq \mu_k(x),$$

$$v_{\overline{D}}(x) \geq v_k(x),$$





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$$\forall k = 1, 2, \dots, p + q.$$

Thus the above system can be transformed to the following system of inequalities:

$$\begin{aligned} \mu_k(x) &\geq \alpha, k = 1, 2, \dots, p + q \\ v_k(x) &\leq \beta, k = 1, 2, \dots, p + q \\ \alpha + \beta &\leq 1 \end{aligned} \quad (11)$$

$$\alpha \geq \beta$$

$$\beta \geq 0$$

$$x \in X$$

Where α denotes the minimum acceptable degree of objective(s) and constraints, and β denotes the maximum degree of rejection of objective(s) and constraints.

Using the IFO problem analogous to the problem transformed to the linear programming problem can be given as:

Maximize $(\alpha - \beta)$

$$\mu_k(x) \geq \alpha, k = 1, 2, \dots, p + q$$

$$v_k(x) \leq \beta, k = 1, 2, \dots, p + q$$

$$\alpha + \beta \leq 1 \quad (12)$$

$$\alpha \geq \beta$$

$$\beta \geq 0$$

$$x \in X$$

This can be easily solved by the simplex method for the solution of the multi-objective linear programming problem by IFO.

Crop Production Planning Problem

We create the following algorithm for obtaining the solution of a multi-objective programming problem in an intuitionistic fuzzy environment using the aforementioned theorem and the approach by [4]:

Step 1: Choose one objective function from the set of k objectives and solve it as a single objective while keeping the limitations in mind. Find the remaining $(k-1)$ objective function values using the obtained solution vectors.

Step 2: To continue with the remaining $(k-1)$ goal functions, follow step 1. The best compromise option will be found if all of the solutions are the same.

Step 3: To create the Positive Ideal Solution (PIS), as shown below, tabulate the solutions so acquired in steps 1 and 2.

Step 4: From Obtain the upper and lower bounds for each objective function from PIS, where f_k^* and f_k' represent the maximum and minimum values, respectively.

Step 5: Using the collection of solutions found in step 4, establish upper and lower bounds for each objective's degree of acceptance and rejection.

For membership functions:

Upper and lower bounds for membership functions

$$U_k^\mu = \max (Z_k(X_r))$$

$$L_k^\mu = \min (Z_k(X_r)), 0 \leq r \leq K$$

For non-membership functions:

$$U_k^v = U_k^\mu - \lambda(U_k^\mu - L_k^\mu), U_k^v = L_k^\mu, 0 < \lambda < 1.$$

In our problem, we have taken $\lambda = 0.2$.

Step 6: MOLP problems (1) can be written as:

Find x such that

$f_k(x) \geq q_k^0$, are the ambition levels provided by the decision maker, and tq_k^0 for each k . Since there is a conflict between all of the goals, intuitionistic fuzzy inequalities are understood to exist in this situation. The next step is to define the membership and non-membership functions for the intuitionistic fuzzy inequalities.

The next step is to define the membership and non-membership functions for the intuitionistic fuzzy inequalities.

Step 7: Construction of membership and non-membership functions

Define the membership and non-membership functions for the uncertain objective functions.

(i). For maximization of objective functions





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$$\mu_k(z_k(x)) = \begin{cases} 1, & z_k(x) \geq u^{acc} \\ \frac{z_k(x) - u^{acc}}{u^{acc} - l^{acc}}, & l^{acc} < z_k(x) < u^{acc} \\ 0, & z_k(x) \leq l^{acc} \end{cases}$$

$$v_k(z_k(x)) = \begin{cases} 0, & z_k(x) \geq u^{rej} \\ \frac{u^{rej} - z_k(x)}{u^{rej} - l^{rej}}, & l^{rej} < z_k(x) < u^{rej} \\ 1, & z_k(x) \leq l^{rej} \end{cases}$$

(ii). For minimization of objective functions

$$\mu_k(z_k(x)) = \begin{cases} 0, & z_k(x) \geq u^{acc} \\ \frac{u^{acc} - z_k(x)}{u^{acc} - l^{acc}}, & l^{acc} < z_k(x) < u^{acc} \\ 1, & z_k(x) \leq l^{acc} \end{cases}$$

$$v_k(z_k(x)) = \begin{cases} 1, & z_k(x) \geq u^{rej} \\ \frac{z_k(x) - l^{rej}}{u^{rej} - l^{rej}}, & l^{rej} < z_k(x) < u^{rej} \\ 0, & z_k(x) \leq l^{rej} \end{cases}$$

(iii). Define the membership and non-membership functions for the uncertain constraints (\leq_{int}).

$$\mu_i(A(x)) = \begin{cases} 1, & A(x) \leq b_i \\ \frac{\tau_i^{acc} + b_i - A(x)}{\tau_i^{acc}}, & b_i < A(x) < b_i + \tau_i^{acc} \\ 0, & A(x) \geq b_i + \tau_i^{acc} \end{cases}$$

$$v_i(A(x)) = \begin{cases} 0, & A(x) \leq b_i + \tau_i^{rej} \\ \frac{A(x) - (b_i + \tau_i^{rej})}{(\tau_i^{acc} - \tau_i^{rej})}, & b_i < A(x) < b_i + \tau_i^{acc} \\ 1, & A(x) \geq b_i + \tau_i^{acc} \end{cases}$$

(iv). Define the membership and non-membership functions for the uncertain constraints (\geq_{int}).

$$\mu_i(A(x)) = \begin{cases} 1, & A(x) \geq b_i \\ \frac{A(x) - (b_i - \tau_i^{acc})}{\tau_i^{acc}}, & b_i - \tau_i^{acc} < A(x) < b_i \\ 0, & A(x) \leq b_i - \tau_i^{acc} \end{cases}$$

$$v_i(A(x)) = \begin{cases} 0, & A(x) \geq b_i - \tau_i^{rej} \\ \frac{(b_i - \tau_i^{rej}) - A(x)}{(\tau_i^{acc} - \tau_i^{rej})}, & b_i - \tau_i^{acc} < A(x) < b_i - \tau_i^{rej} \\ 1, & A(x) \leq b_i - \tau_i^{acc} \end{cases}$$

Where $\tau_i^{acc}, \tau_i^{rej} = \delta \tau_i^{acc}, 0 < \delta < 1$ are tolerances for membership and non-membership functions respectively. In our problem, we have taken $\delta = 0.1$.

Step 8: In this step we apply intuitionistic fuzzy optimization technique for multi-objective linear programming (MOLP) problem and get an equivalent linear programming problem as

Maximize $(\alpha - \beta)$

$$\mu_k(x) \geq \alpha, \quad k = 1, 2, \dots, p + q$$

$$v_k(x) \leq \beta, \quad k = 1, 2, \dots, p + q$$

$$\alpha + \beta \leq 1$$

(13)

$$\alpha \geq \beta$$

$$\beta \geq 0$$

$$x \in X$$



**Bharathi and Geetha****Application of Fuzzy Linear Programming Model in Agricultural**

A portion of India is home to Sikkim as well as the highlands of West Bengal and the North-eastern States. The entire region covers 0.8 million hectares. Furthermore, Sikkim and the hills of West Bengal and the North-eastern States are situated in the transitional zone between India's second and third geomorphic phases as well as the remaining vein of the eastern Qinling Mountains. A relatively complete geomorphic succession is formed by the progressive decline from the tectonic erosion of low and medium mountains in the West and Southwest to the tectonic denudation hills, loess hills, inclined (hillock) plains, and alluvial plains. In contrast, Sikkim and the hills of West Bengal and the Northeastern States experience a continental monsoon climate in the northern temperate zone. This climate features four distinct seasons: spring, summer, autumn, and winter, as well as regular variations in heating and cooling groups. While spring is dry and less rainy, winter is lengthy, cold, and dry; there is little snow and rain. In contrast, spring is cold, dry, and windy. In addition, autumn has a brief season and a cold environment, while summer is somewhat hot and rainy. An average monthly temperature of 25.9°C is recorded in August, the warmest month, and 2.15°C is recorded in January, the coldest month. The annual average temperature is 15.6°C. The frost-free period is 209 days, with an average annual rainfall of 542.15 mm. It receives roughly 1,869.7 hours of sunshine a year. The Indian states of Sikkim, the highlands of West Bengal, and the north-east.

Optimal Solution

Area of Wheat = 12000

Area of Corn = 15000

Area of Oil crops = 18000

Objective Values are $f_1 = 12000, f_2 = 15000, f_3 = 18000$.

RESULTS AND DISCUSSION

This work studied the mathematical model of fuzzy linear programming in depth and found their optimal solutions by analyzing the data between two different functions, guided by a class of multi-objective fuzzy linear programming problems with elastic constraints. Fuzzy linear programming was then applied to agricultural economic management, with five metropolitan regions in Sikkim and the hills of West Bengal and Northeastern states serving as entry points to confirm the fuzzy linearity's findings. Determining the extent of expansion and contraction, after which fuzzy linear programming is used to solve and decompose them to produce the optimal inequality solution using MATLAB. With fuzzy linear programming, projections for agricultural economic management could be more precise. The results show a good potential for application and show persistently changing trends. Generally speaking, agricultural economic management can benefit greatly from the use of fuzzy linear programming, as this approach has both theoretical and practical backing.

CONCLUSION

We characterized the former crop planning issues as intuitionistic fuzzy inequalities, considering objective functions and constraints as such since poor parameterization prevents us from specifying yield or profits as crisp inequalities. So, it makes sense that MOLP difficulties would naturally become intuitionistic fuzzy MOLP problems. Using the proposed techniques, we have employed an intuitionistic fuzzy approach to transform an intuitionistic fuzzy MOLP problem into a crisp linear programming problem. An ideal crop production model has been obtained by implementing the developed method. Using the largest amount of land that the farmer has access to, the created method maximizes land utilization while satisfying restrictions and achieving goals in an exciting manner. This output shows that, with matching target values of 12,000, 15,000, and 18,000, respectively, the best solution allots 12,000 units of land to wheat, 15,000 units to corn, and 18,000 units to oil crops. Consequently, crop modeling issues can be effectively handled by applying the suggested approach.





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Table 1: Positive Ideal Solution

	f_1	f_2	f_3	...	f_k	X
$\max f_1$	f_1^*	$f_2(X_1)$	$f_3(X_1)$...	$f_k(X_1)$	X_1
$\max f_2$	$f_1(X_2)$	f_2^*	$f_3(X_2)$...	$f_k(X_2)$	X_2
$\max f_3$	$f_1(X_3)$	$f_2(X_3)$	f_3^*	..	$f_k(X_3)$	X_3
\vdots						\vdots
\vdots						\vdots
$\max f_k$	$f_1(X_k)$	$f_2(X_k)$	$f_3(X_k)$...	f_k^*	X_k
	f_1'	f_2'	f_3'	...	f_k'	

Table 2:Wheat, Corn and Oil crops in different seasons

Region	Wheat	Corn	Oil crops
A1	(6,980.50, 6,580.25)	(10,158.2, 14,856.5)	(28,975.6, 32,458.6)
A2	(15,864.5, 6,878.6)	(20,156.8, 25,458.6)	(45,628.5, 48,658.5)
A3	(10,880.5, 14,680.95)	(38,560.5, 51,268.5)	(7,485.5, 6,685.4)
A4	(20,058.5, 26,585.4)	(36,875.5, 40,258.5)	(50,258.5, 54,685.5)
A5	(30,586.5, 24,865.8)	(25,687.3, 30,558.5)	(42,005.8, 46,857.5)





RESEARCH ARTICLE

A Study on the Effects of the COVID-19 Caused Shutdown has on the Workers the Leather Processing Sector in South Asia

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ABSTRACT

This study investigates how the COVID-19 pandemic and the subsequent statewide outbreak and lockdown affected workers in the leather and footwear manufacturing industries in India, specifically in southern India, which is located in southern Asia. The post-employment experiences of workers are the primary subject of this research. They ceased to exist in the industry when a large number of staff members were temporarily laid off or when lockdown procedures were reduced. Interviews with workers were the source of the information acquired here. Look into issues such as whether or not employees were paid, whether or not they had access to social security, and whether or not they were given assistance during the Lockdown that was caused by the pandemic.

Keywords: Lockdown of Covid 19; employees of the leather industry; impacts on the industry; various suppliers, etc., are some of the key words here.

INTRODUCTION

The COVID-19 pandemic is a significant threat to the public's health and has affected practically every country in the world. The epidemic caused a level of destruction and suffering that has never been seen in recent human history. A huge economic calamity has also been caused by the disease, and as a result, some nations are currently experiencing a recession. According to projections made by the International Monetary Fund (IMF), expansion is on the horizon

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for the global economy. The outbreak and subsequent response would cause a decline of 4.9 percentage points in the economy of India in the year 2020. The effects of measures such as the government of India shutting down the entire country in March were felt. The first quarter of the fiscal year 2020-2021 saw a significant reduction in GDP of a staggering 23.9 percent. This was a significant and shocking drop [1]. Employees in the private sector had their lives disrupted because of the disease and the statewide lockdown. Millions of exodus employees moved to other parts of the country in the early days of the lockdown as a result of significant job losses and the unanticipated lack of various sources of income in metropolitan regions around the country. As soon as the strike was called off, a serious humanitarian disaster broke out as hundreds of workers started making their way back to their towns, many of them walking thousands of kilometers to get there on foot. During this time, migrant workers gained to prominence, which forced the government to take action in response. To be of any assistance to them, prompt action is necessary. During this time, there was a lack of discussion in the major media outlets regarding the difficulties that were affecting workers in industrial jobs in the private sector. The disruptive effects of the pandemic on global supply chains prompted a chain reaction that has severely harmed almost all industrial sectors in India, including the readymade garment, leather, and footwear industries, amongst others. Throughout the course of their existence, these industries have provided work for millions of people in Indian cities. The value of exports experienced by the leather and leather product business dropped by 83 percent between the months of April and May. Media sources indicate that the industry as a whole endured widespread wage losses and job terminations as a result of the event; however, the exact extent of its impact on personnel is uncertain. According to an article that was published in the Times of India in April, the Tamil Nadu labor department received up to 1600 phone complaints from employees in the private sector about not being paid their paychecks, having their salaries reduced, and being let off [2].

REVIEW OF LITERATURE

Supply chain risk management has become an increasingly important topic in academic research. Literature on this topic introduces proactive and reactive policies for effective supply chain risk management. Proactive policies are formulated to mitigate the probability of occurrence of risk events (Chen et al., 2015, Chowdhury et al., 2019, Scholten et al., 2014, Sreedevi and Saranga, 2017) [11]. Reactive policies are established to minimize the impacts of risks and ensure smooth recovery (Hishamuddin et al., 2015, Ivanov et al., 2016, Ivanov, 2019, Ivanov, 2020b, Paul et al., 2014, Paul et al., 2015) [12]. Operational risks that occur due to managerial problems such as quality and long lead time concerns are controllable. Proactive strategies can control and mitigate the probability of these risks before they occur (Chen et al., 2013, Chowdhury et al., 2019) [13]. However, reactive policies are needed for disruptions arising from disease outbreaks, earthquakes, and terrorist attacks, as their occurrence is unpredictable and outside the control of business firms (Chen et al., 2015, Darom et al., 2018, Mithun Ali et al., 2021) [14]. In both cases, proper formulation of recovery strategies for managing disruptions is necessary to minimize the overall impact of disruptions on operations (Blos & Wee, 2020) [15]. Formulating recovery strategies to return to normal or better operational states after catastrophic events is vital to rapid recovery and survival (Ponomarov & Holcomb, 2009) [16]. Results of previous research show that 80% of companies that failed to design recovery strategies for supply chain disruption during major outbreaks have closed down their operations within two years after the event (Cerullo & Cerullo, 2004) [17]. Statistics indicate that the frequency of such major supply chain outbreaks has increased in recent years. For example, the World Health Organization (WHO) has tracked more than 1,400 epidemic outbreaks between 2011 and 2018 (Hudecheck, Siren, Grichnik, & Wincent, 2020) [18]. As such, developing strategies for recovering from a major outbreak has become critical for the long-term survival of supply chains. Yet, surprisingly, the extant literature on major epidemic and pandemic outbreaks mostly considers humanitarian supply chain issues. There is a lack of studies on how traditional commercial supply chains can quickly recover from epidemic or pandemic outbreaks (Clarke & Boersma, 2020a) [19].

ONSET OF COVID-19 AND ITS EFFECTS

The investigation starts out with a concise overview of the leather business in India as well as an investigation into the influence that the COVID-19 epidemic has had on the leather supply chain. The principal results are presented in



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two parts following a brief introduction to the methodology of the study and a brief introduction to the participants. The first part discusses the situation of employees during the intensive lockdown, and the second part discusses the situation after restrictions were lifted to enable the opening of workplaces. The conclusion is a condensed summary of the most important findings from the study.

Bringing some much-needed clarity to the Indian Leather Industry

Over the course of the past two decades, India's leather industry has undergone tremendous expansion and development. During this time period, the nation has transitioned from being a major supplier of raw materials to a value-added exporter of leather and leather goods that are widely significant on the global market. The leather industry in India accounts for approximately 12.93% of the total production of leather worldwide [3]. India is currently in second place across the world when it comes to the manufacturing of leather shoes. The leather sector is one of India's top ten sources of foreign currency because it accounts for 3.3% of the world's total leather shoe exports, ranks second in the export of leather garments, and third in the export of leather saddlery. During the 2018-2019 fiscal year, the total value of its exports was \$5.69 billion USD. As a result of the Indian government's recognition of the sector's untapped growth potential, the Make in India initiative has included the sector as one of its top priorities. According to estimates provided by the Association of Small and Medium Enterprises in Asia and the Pacific (ASSOCHAM), micro, small, and medium-sized enterprises (MSMEs) make up more than 90 percent of India's leather sector⁴. Tamil Nadu is responsible for producing almost half of all leather and leather goods exported from India, as well as accounting for sixty percent of India's total tanning capacity [5]. The leather industry in Tamil Nadu established both Central Effluent Treatment Plants (CETPs) and independent Effluent Treatment Plants (ETPs) in response to pressure from the outside community, mainly from the court and civil society. These plants are intended to manage the hazardous waste that the leather industry generates. Even while these nine metrics represent undeniable advancements in the direction of environmental sustainability, the focus that social indicators should have been getting has not yet been given to them.

What benefits did covid-19 bring to the leather industry?

The COVID-19 outbreak has had a significant and negative influence on the Indian economy as a whole, with the exception of the most fundamental of services. The worst affected were the textile, garment, and footwear industries, all of which are highly dependent on international trade. These fields provided employment for a significant number of city residents, which was an additional desirable benefit. Demonetization in 2016 and the implementation of the Goods and Services Tax (GST) in 2017 are two examples of acts taken by the central government that have contributed to the significant challenges that the Indian leather industry has been suffering for a number of years [6].

Implications Caused by International Factors

Lockdowns in China, the United States, and European nations owing to the COVID-19 epidemic generated massive disruptions in the leather and footwear supply chains as early as January 2020. As a result, the sale of fashion and leather items in export-based markets dropped by as much as fifty percent. Despite the fact that the entirety of the leather goods value chain is based in India, key inputs such as chemicals, adhesives, dyes, and footwear components (soles, buttons, and zippers) are imported from China. As early as the month of February, Indian exporters were already feeling the consequences of lockdowns in the United States and Europe, two of the main markets for imported leather and footwear.

The Repercussions of the Lockdown Implemented Nationwide in India

On March 23, 2020, because to the COVID-19 epidemic, the government instituted a lockdown across the country. During the period of extreme lockdown, which lasted until the first week of June, practically all economic activity came to a halt, with the exception of the delivery of essential services such as food, water, energy, and medical care. This situation persisted until the first week of June. Because of the stringent surveillance and regular inspections conducted by government officials during the months of April and May, nearly all tanneries, shoe manufacturers, and informal workshops were had to shut their doors. A total of approximately 150,000 individuals were impacted when businesses in the leather industry in the Vellore area closed their doors. According to the head of the Centre for



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Leather Exports (CLE), a total of USD 200 million worth of orders were canceled by brands and merchants in the United States and Europe in just the month of March. The payment for items that had already been shipped was withheld, and the suppliers were asked to delay their shipments while the delay was being negotiated.

The Repercussions of the Lockdown Implemented Nationwide in India

On March 25, 2020, because to the COVID-19 epidemic, the government instituted a lockdown across the country. During the period of extreme lockdown, which lasted until the first week of June, practically all economic activity came to a halt, with the exception of the delivery of essential services such as food, water, energy, and medical care. This situation persisted until the first week of June. A total of approximately 150,000 individuals were impacted when businesses in the leather industry in the Vellore area closed their doors. According to reports in the media, during this time period, the vast majority of enterprises did not pay their employees⁸. Just in the month of April, businesses canceled orders totaling over one billion dollars, including 370 million dollars' worth of business for the leather industry in Tamil Nadu [9]. According to the General Secretary of the Tamil Nadu Trade Union Center (TNTUC), more than half of the local workforce was unable to return to work after the lockdown restrictions were lifted. During the period in which the entire nation was placed under lockdown, the federal and state governments each launched supplemental programs designed to assist people who had lost their jobs in addition to their financial resources. This comprised public distribution system (PDS) initiatives to supply subsidized and free food grains to low-income households, as well as PDS- and bank-based cash transfer programs. Also included in this category was the provision of public distribution system (PDS) projects. On the other hand, there were not many reports of these programs actually being beneficial to the people they were designed for. Massive relief efforts were coordinated across the country by non-governmental organizations, labor unions, and other philanthropic organizations [10].

Plan for the Research**The Goals of the Research**

This study was carried out with the intention of evaluating the condition of the leather and footwear manufacturing business in Tamil Nadu before, during, and after the COVID-19 induced shutdown (which, for the sake of convenience, lasted from the 23rd of March until the first week of June). Once India finished reopening its businesses after a shutdown. Interviews with workers served as the major source material for this investigation because these individuals were the only ones who could testify to the employment and labor rights conditions that persisted throughout the outbreak. Along with the more widespread effects of the pandemic and lockdown, several factors, including employees' availability to food and nutrition, healthcare, payment of salary, and social security, were taken into consideration. Within the scope of our study, we looked into the following subthemes:

The Methodology of Research

The data for the study were compiled through the use of in-depth interviews with members of the labor force. As a result of the lockdown, in-person meetings were not permitted; consequently, the vast majority of the interviews took place over the phone. Even when some of the previous limitations were lifted, researchers did their best to avoid any kind of interaction with staff. This was done out of an abundance of caution. In the months of August and September of 2020, the gatherings were held in the Vellore region of the state of Tamil Nadu. For the purpose of the investigation, a detailed questionnaire that included both closed and open/semi-open questions was developed. The researchers decided to apply a convenience sample technique in order to maximize data collection in this one-off case. Specifically, they conducted interviews with the employees who were the most easily available and who agreed to take part in the study. The group doing the research had to prevail over a variety of challenges. Some of the respondents, particularly those who had already returned to work after the lockdown, were hesitant to share specifics about their workplaces because they were afraid that being honest could have a negative impact on their jobs. Many individuals were concerned that they would lose their jobs if management found out that they had sought employment elsewhere and then decided to fire them. The extended nature of the telephone interviews (which often lasted between 30 and 45 minutes) posed a number of difficulties. Due to the limited sample size and the non-random selection process, it was challenging to interpret the data and difficult to generalize the findings in



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accordance with the methodology of the study. Due to these impediments, the research did not look into significant components of the workforce in the leather sector, such as gender and caste, even though they are important. Researchers were unable to conduct individual interviews with leather industry home workers as a result of the lockdown; nevertheless, they did engage in multiple rounds of talk with groups in Ambur. This research was aimed to quickly investigate the status of leather workers during the pandemic, and its results will be beneficial in better appreciating the challenges experienced by these individuals. Despite certain methodological limits, the research was designed to accomplish this goal. The findings provide important insights into the assistance that was provided to workers during this time, and the conclusion proposes a framework for immediate action by the government and corporations to better assist workers.

Features of the Representative Sample

In the course of this study, interviews were conducted with fifty different leather workers. The sample consists of people of varying ages and genders, with a disproportionate number of more experienced professionals. There is also a wide range of ages present. Before the lockdown, 22 of these persons were engaged at leather shoe manufacturers, 17 in tanneries, and 11 in job work units.

Main Findings

The Situation of Workers during the Intense Lockdown

In this part, we report the data we gathered on the economic, social, and health conditions, as well as the extent of COVID-19 aid, that employees faced during the lockdown.

Inability to compensate Wages and Salaries

Many of the employees surveyed said they had stayed on the job until the lockdown's March 25, 2020, factory closure. But just six people said they had gotten their entire March paycheck. Thirty-five people said they had only gotten a portion of their March pay, typically for the amount of days they had really worked. Even though they had worked more than 20 days in March, nine employees said they had not been paid. Based on interviews, it seems that the majority of leather workers in the Vellore area were not paid during the lockdown, and that those who were paid only got half salaries at best. Workers were forced to fend for themselves throughout the crisis since their companies offered them no real assistance.

Decreased Incomes and Rising Debt Levels

All production and services outside of India's key sectors came to a halt as a result of the lockdown. The results of this research support the premise that the lockout had a negative effect on the household earnings of the majority of employees, since almost all respondents reported a decrease and the majority had to borrow money to get through the crisis. Fifty percent of those who filled out the survey said they had borrowed money to get by during the lockdown. The shutdown and consequent loss of pay had clearly pushed employees to the brink, compelling them to borrow money to meet basic essentials like food. Six respondents said that they have used their credit to pay for healthcare costs.

The Safety Net Is Very Far Away

Many of the employees surveyed did not participate in the Employee Provident Fund (EPF) because they were not enrolled. Withdrawals from employees' EPF accounts were sanctioned by the federal government during the epidemic. Three people out of fifty respondents said they have used the plan to withdraw funds from their EPF accounts. However, despite their familiarity with the plan, eight respondents claimed they had no intention of using it.

COVID-19-Specific Measures for Aid

Based on interviews, it seems that the public distribution system (PDS) in Tamil Nadu is the most accessible relief programme for employees and their families, while other programmes launched by the state and national governments have helped a very limited number of leather workers. Forty-seven of the fifty employees surveyed for





the research reported receiving free grains as part of their compensation, and During the lockdown, the state government donated food via the PDS, and 45 respondents verified receiving a one-time cash transfer of INR 1000.

Layoffs and terminations that violate the law

In a survey with 50 participants, 16 people reported being unable to return to their previous jobs when the lockdown was lifted and production began. Nine were part-time or contract workers, while the other seven were full-timers or salaried employees. There were nine males and seven women in the labour force. There is little doubt that layoffs and terminations have touched every demographic of employees, regardless of job position or gender.

Worker uncertainty and ProClarity upon returning to the labor force

Upon approval from the Tamil Nadu state government, manufacturing might resume in the state at the start of June 2020. Since then, numerous Vellore tanneries and shoe manufacturers have had either full or partial worker involvement.

Safeguards against COVID-19

The interviews showed that most businesses made steps to implement basic precautionary measures to restrict the spread of COVID-19 after restarting operations, indicating that the government's tight regulations for industry seem to have guaranteed this.

New Difficulties in Getting to Work

All modes of public and commercial transportation stayed grounded during the first "unlocking" stages. The interviews showed that most leather workers in Vellore relied on public buses and private auto-rickshaws, which presented significant challenges on the way to and from work.

A typical Schedule Variations

Fifteen of the thirty-seven employees who answered the question said that their weekly hours had decreased since the lockdown began. Sixteen employees reported no change in their number of working days after returning to their jobs. This suggests that a greater share of the workforce that returned to the workforce saw a reduction in the number of hours they worked and, as a result, their salaries.

Time Off, Production Goals, and Overtime

Twelve respondents said they had put in extra hours before the lockdown, but only six were requested to do so when they got back to work afterward. Many respondents, however, said that they often put in more than eight hours a day, even if their employers did not consider this to be overtime.

Pay Cuts and Salary Reductions

After returning to work, respondents surveyed did not notice any significant changes in the regularity of their salary checks. They were paid on a monthly basis, and that was the most common response. As a result of the lockdown, employees saw a decrease in their net monthly earnings compared to the period before the lockdown. Although no responder had been paid less than INR 4000 before to the shutdown, at least twelve said they were paid that much or less after work resumed. Over the course of the lockdown, eleven respondents got paychecks totaling between INR 4001 and INR 7000.

The Crisis and Its Effects on People Working from Home during COVID-19

Large numbers of unseen home workers are employed by India's leather industry. Numerous ladies in Ambur sew shoe uppers at home. Subcontractors and agents, who are mostly male, are the usual employers of home-based employees. These latter workers take orders from shoe manufacturers and then deliver their finished products to women in outlying communities around Ambur. There was just a little quantity of work to go around for the remainder of the year. Home workers in Ambur might make anything from INR 1000 (about US\$15) to INR 3000 (about US\$250) each month. Since subcontractors and agents representing supplier factories did not pay out any





work commissions to home-based employees during the countrywide lockdown, these workers were unable to make a living. And despite their having fulfilled orders before to the lockdown, agents never paid them for their work. Home workers did not get aid during the epidemic since they do not qualify for national social security programmes like the Employees' Provident Fund (EPF).

CONCLUSION

The research gave information on the position of employees in the leather industry during the statewide lockdown and after restrictions were lifted, despite a small sample size and the difficulties created by the continuing epidemic. The lockdown had a severe detrimental effect on many, if not most, employees, making it difficult for them to meet their most fundamental demands. The results show that the supply businesses did not adhere to proper procedure while laying off employees. Unfair and sudden layoffs and firings have become commonplace in many manufacturing facilities. There have been occasions when employees have been pressured into resigning in order to get payment.

SUGGESTIONS

The following steps should be taken by manufacturers, distributors, retailers, and suppliers to ensure that leather industry employees are effectively supported during and after the epidemic, and that their already precarious positions are not weakened.

Brands and Stores from Around the World

- For suppliers to go back to work, brands and stores should release whatever money they've been holding back, Brands and retailers should maintain open lines of contact with their suppliers to provide enough assistance and address any issues that may arise throughout the supply chain, It is the responsibility of the brands to guarantee that their supply chain employees get their regular pay during the shutdown. There should be no lag time in paying employees for their time during the epidemic, It is the responsibility of manufacturers and retailers to guarantee that all employees in their supply chains, including those in subcontracting and remote roles, have access to appropriate social protections, They need to watch out for unlawful firings and layoffs by suppliers, To evaluate the additional human rights risks that have evolved in the wake of COVID-19, brands should do human rights due diligence throughout their supply chains, including the sub-contracting and home-working sectors.
- Companies should take measures to provide a livable wage for all employees in their supply networks, In order to guarantee that all employees are paid a salary that allows them to provide for their families, it will be necessary to revise buying procedures, pricing structures, and planning models, Companies should collaborate with their suppliers to establish and maintain effective grievance redressal systems that may help industrial employees with their issues. Companies selling such products have a responsibility to safeguard their employees from any adverse effects resulting from customer purchases. Brands should pay their suppliers enough money to provide fair working conditions and a livable salary for their employees.

Suppliers

During the lockdown and the months after it, suppliers should pay all employees in their factories and supply networks their regular salaries. Workers should be paid in full for the months they worked during the epidemic. Businesses that had employees' pay withheld during the lockout should take quick action to pay them in full.

- It is unacceptable for vendors to engage in unlawful employee terminations. It is the responsibility of suppliers to make sure their employees have access to and are able to fully use any available social protection programmes, Manufacturers and their representatives should have an open discourse about issues affecting employees and the community. If suppliers want to help industrial employees, they need to set up and keep up effective channels for resolving complaints, To guarantee worker safety, suppliers must adhere to all government regulations, including those imposed for COVID-19. Suppliers should provide paid sick days and make it easy for employees





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to take them without fear of retaliation, Management at factories should provide enough transportation options for employees, particularly those who must travel long distances to reach their workplace.

Government

- In order to promote and fully administer COVID-19 assistance programmes, government agencies should enhance their communication and outreach methods. Factory compliance with government rules published to prevent the spread of COVID19 at workplaces should be monitored and inspected on a regular basis. All employees should be paid in full by the government throughout the lockdown. In this context, formal notices should be sent out to relevant industries. The Department of Labor has to make sure that no factories are engaging in unlawful firings and layoffs. Corrective action should be made if firms resort to such methods.

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Fig. : 1 Workers in the leather sector demonstrating in front of other industries to demand the provision of relief supplies





The Relationship between Severity of Dysmenorrhea and Menstrual Characteristics among Deaf and Mute Girls

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ABSTRACT

The purpose of this study is to find out the association between severity of dysmenorrhea and menstrual characteristics like age of first menarche, duration of menstruation, length of menstrual cycle. A cross sectional School based study was conducted among 66 deaf and mute girls aged 11-19 from various deaf and mute schools. Structured based questionnaire and verbal multidimensional scoring system (VMSS) grading used for measure severity of menstruation for data collection and analyzed menstrual characteristics and Severity of pain among deaf and mute adolescent girls with primary dysmenorrhea. Total 66 girls participated in the study out of them 56 (86.3%) girls reported menstruation is painful but seldom inhibits normal activity; analgesics are seldom required; mild pain according to VMSS. Among them majority of the girls reported (51.5%) ideal age of menarche 12-13 years even they reported normal length and duration of menstrual cycle. The severity of dysmenorrhea was no associated with menstrual characteristics age of first menarche($p=0.15$), duration of menstruation ($p=0.08$) and length of menstrual cycle ($p=0.22$), no of sanitary pads used per day($p=0.19$). present study found no relationship between body mass index and dysmenorrhea($p=0.82$). The study indicate no association between menstrual characteristics like age of first menarche, duration of menstruation, length of menstruation with severity of dysmenorrhea.

Keywords: Body Mass Index , Deaf and Mute Girls , Dysmenorrhea, Menarche





INTRODUCTION

At the age of reproductive life in all women, certain changes occur in the reproductive organs, it affects the reproductive functions mainly during the phases of menarche to menopause due to certain hormonal changes occurring in the body during this phase. In every girl, the first menstrual period is a most important event during puberty which is a natural physiological process, which is defined as a menarche. From the beginning of a period to the next beginning of the period is called menstrual cycle. Menstruation occurs at age of puberty more common between 11-15 years and mean age of it 13 years. When women reaches at her 40s or 50s menstruation naturally ceases gradually due to naturally decrease reproductive hormones in the body which result in end of women menstrual cycle and it is defined as menopause [1,2,3]. Girls with disabilities may experience this phase differently and sometimes more negatively compare to nondisabled girls. In our daily life we all required speaking as well as communication during daily work but normal people who do not know the sign language they cannot easily communicate with deaf and mute person which can create misinterpretation and found communication problems. Reproductive health is a major health concern in every girls and specially girls with disability. And if they cannot convey their problems or needs due to communication barrier with the reproductive health services provider then they may have difficulty in raising issues of menstruation and related problems they faces[4,5]. Most of the adolescent complained about the dysmenorrhea and many other issues related to menstruation which is a very common gynecological problem. Dysmenorrhea is define as a pain occurs before or during the period of menstruation, or during both of the time. It is commonly occurs cyclical lower abdominal region pain or pelvic pain and sometimes it may also radiating in back and thigh region. It begins soon after menarche. Many of the girls complaining about pain, discomfort and other menstrual related symptoms typically start at the onset of menstrual flow or occurs a few hours before or after onset of menstruation, and remains last for the first 24-48 hours also[1,2,3].

Dysmenorrhea is classified basically in two types: primary dysmenorrhea and secondary dysmenorrhea. Primary dysmenorrhea is define as a pain with no any kind of pelvic pathology and almost always first occurs among women 20 years or younger after their ovulatory cycles become established. And Secondary dysmenorrhea is caused by underlying pelvic conditions or pathology and it is more common among women older than 20 years of age[6,7]. Adolescence is a phase, in these period many of the girls faces significant cognitive and psychological even behavioral changes. It continue through period of adolescence and also after most of the physical changes of puberty have already taken place in body. Major physical and psychological changes occur in every young woman and most of them complaining likes irregular bleeding, pain during menstruation, mood swings, anger, irritated, loss of appetite, loss concentration, fatigue, headache, body pain etc. during these phase. During the period of adolescence Serious gynecological pathology is rare to found, but menstrual related problems are most commonly noticeable. This difficult phase even more challenging in adolescent and especially for girl with disability and their families. During these phase special attention and care is needed, because they found difficulties to express their feelings and pain. Even Sometimes they have received negligence from society also[8]. According to the various research studies on adolescence girls with disabilities have found limited knowledge to health-related details and issues, which including even basic knowledge about their own physical growth and bodily changes. Due to communication barrier with deaf and mute girls various studies have reported that they faced several challenges during accessing reproductive health also[8,9,10]. Even we found limited studies related to dysmenorrhea and other related to reproductive health in deaf and mute girls and with other disabilities. Dysmenorrhea is the most prevalent menstrual irregularity among adolescent girls In previous study was reported 95.5% of the total girls[15]. Researchers reported that people with hearing impairment faced several challenges during accessing reproductive health due to difficulty in communication with them[4]. Thus, a cross-sectional study was conducted among deaf and mute adolescent girls with following objectives: To evaluate the association between severity of primary dysmenorrhea and menstrual characteristics.





MATERIAL AND METHODS

In the present study cross-sectional design was used to gather information about the relationship between severity of dysmenorrhea with menstrual characteristics and primary dysmenorrhea with body mass index among deaf and mute girls. The study was conducted with deaf and mute girls from various deaf and mute schools. Informed written consent was taken from all the students, parents and school authority before their participation in the study. Ethical approval was obtained from ethical board also. Participants included in the study were explained about the aim and procedure of the study. Explained about the questionnaire and included each and every content, convey all this information by sign language knowing teacher via sign language to all participants of the study. All of participants were explained that if they feel uncomfortable then they could discontinue the study at any time. As per the selection criteria total sixty six (66) students with hearing impairment were enrolled in the research study. The selection criteria as follows: all type of hearing impaired girls who are unmarried, use or understand sign language, girls who volunteered to participate. Age 11-19 year old and girls who attained menarche were enrolled and Girls with any systemic, chronic or gynecological disease were excluded from the study. The presence of dysmenorrhea was confirmed by inquiring the students. Data was carried out by various deaf and mute schools and Overall 66 girls were enrolled from different grades of school. Demographic and menstrual characteristics information were collected via questionnaire which were completed by students with the help of sign language knowing teacher. In demographic description includes age, height, weight and body mass index, family history. In Menstrual characteristics form information includes age at first menarche, duration of menstrual cycle, length of menstrual cycle, no of sanitary napkins used per day. The severity of dysmenorrhea was assessed by verbal multi-dimensional scoring system (VMSS), in which scale grade 0 means menstruation is not painful and daily activity is unaffected. Grade one means mild pain, menstruation is painful but seldom inhibits normal activity, analgesics are seldom required. Grade 2 means moderate pain, daily activity is affected; analgesics required and give sufficient relief so that absence from school is unusual. Grade 3 means severe pain, activity clearly inhibited; poor effect of analgesics vegetative symptoms(headache, fatigue, vomiting & diarrhea).

RESULTS

In our study, sixty six deaf and mute girl students were participated, we evaluate the relationship between severity of dysmenorrhea with menstrual characteristics like age of menarche, duration of menstruation, length of menstrual cycle, no of sanitary pads used per day and body mass index with dysmenorrhea. Data related to Menstrual characteristics details and BMI were gathered from all 66 deaf and mute students. Collected data for this study were arranged and analyzed with simple percentages, frequency count and Chi-square test. The relationship between the severity of dysmenorrhea and menstrual characteristics was determined by used of chi square test. Data analysis was done by used of Statistical Package for Social Sciences (SPSS) software version 23.0. In present study, average age of the participants was 15.74 ± 2.24 years range from 11-19 years. Details about menstruation and related characteristics namely age of menarche, duration of menstruation, length of menstrual cycle, onset of pain, duration of pain has been evaluated. As per the previous study result shows Majority of (86.3% n=57) girls reported grade 1(mild pain), analgesics seldom required, others reported grade 0 (4.5%) and grade 2(9.1%)[12]. According to VMSS dysmenorrhea severity grading mild painful menstruation and analgesics seldom required among (86.3%)deaf and mute girls and other girls (9.1%) reported moderate menstrual pain and analgesics required and give sufficient relief so that absence from school is unusual. *p-value<0.05, considered significant VMSS= verbal manual scoring system, χ^2 = Chi square As per the above chi square test reports that majority of the girls started their menstruation at the age of 12-13 year and found no association between menstrual characteristic age of first menarche and severity of dysmenorrhea. Result shows Menstrual characteristics which follows age at first menarche ($\chi^2=13.06$, "p-value" 0.15), majority of the girls (95.0%) girls reported <7 days of menstrual duration we found no association between severity of dysmenorrhea and duration of menstruation ($\chi^2=6.73$, "p-value" 0.08), overall 75.5 % girls have ideal length of menstrual cycle reported mild to moderate pain, we found no association between severity of dysmenorrhea and length of menstrual cycle ($\chi^2=8.14$, "p-value" 0.22), number of sanitary napkins used per day



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($\chi^2=8.60$, “p-value” 0.19). Figure 1 represent that the relationship between menstrual characteristic age of first menarche with severity of dysmenorrhea in which we found no association between menstrual characteristics and severity of dysmenorrhea. Figure 2 shows 50.0% girls reported < 7 days duration of menstrual cycle which is routine duration of menstruation and we found no association between severity of dysmenorrhea. Figure 3 shows maximum girls reported ideal length of menstrual cycle 29-35 days but we found no association between severity of dysmenorrhea. Figure 4 represent menstrual characteristics no of sanitary pads used per day which is important as a part of menstrual hygiene awareness. We found no association between menstrual characteristic no of sanitary used per day and severity of dysmenorrhea.

DISCUSSION

Many different studies worked on menstruation, dysmenorrhea and reproductive health etc. among general population. But lack of the data was found among deaf and mute girls population and other especially abled children regarding reproductive health[20]. Present cross-sectional study was needed due to lack of data available related to dysmenorrhea and its relationship among deaf and mute girls. The results of our previous study confirms that, dysmenorrhea was seen in majority (95.5%) of the deaf and mute girls[12]. In previous research, the frequency of pain during menstruation was 82.2% among Indian secondary school adolescents. According to severity of dysmenorrhea Several studies in normal population have shown a significant association between menstrual characteristics and dysmenorrhea, the reason could be related to girls at the phase of menarche early have longer exposure to uterine prostaglandins which related to the higher prevalence of dysmenorrhea[13]. In our study, majority of the girls were reported reference category of 12-14 years for age of menarche showed similar findings reported by some researcher related age of menarche[12,9,14]. We found no significant difference between mean age of menarche and severity of dysmenorrhea. Menstrual bleeding duration of 5 days and over was an important risk factor for dysmenorrhea. In present study 95.4 % girls reported <7 days of Bleeding duration. We found to be significantly associated with dysmenorrhea in the present study. Girls who had bleeding duration more than 5 days had more chance of getting dysmenorrhea. This finding is compatible with the result showing that the risk of dysmenorrhea is higher in women with long menstrual flows[15]. In our study Average length of menstrual cycle (29-35 days) was reported to be normal in majority 75.8% and 16.7 % girls reported 22-28 days and very few girls reported >35 days (7.6%).Hence normal length of menstrual cycle considered as 21-35 days .We did not find the association between length of menstrual cycle and severity of dysmenorrhea. But Some studies have reported that dysmenorrhea is more prevalent in women with longer menstrual cycle[16, 17]. According to Menstrual Hygiene Matters reports females should change their absorbents regularly every 2–6 hours or depend up on menstrual blood flow individually. But lack of evidence of the adequate frequency for changing for comfort and hygiene. But Once the absorbents become wet, it should be changed immediately[18].If not change regularly then it can cause irritation on the inside of the thighs and can lead to infection also. In present study as shown in table 3 majority (72.7%) girls were using two to three absorbent sanitary napkins during menstruation and 24.3 % girls changed them pads <2 per day. Past literature reported 49.0%(96 out of 201) girls were changed sanitary protections three or more times per day. Even they found that the frequency of absorbent change was significantly associated with school attendance[19].

CONCLUSION

In this study, we observed that many of the girls reported primary dysmenorrhea and it is as common in deaf and mute girls also like other girls. Menstrual characteristics were important factors in dysmenorrhea. We conclude that, we found no association between menstrual characteristics like age of first menarche, duration of menstruation, length of menstruation, number of sanitary pads used per day with severity of dysmenorrhea.

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Table 1 Association between severity of dysmenorrhea and menstrual characteristics.

Menstrual Characteristics	N (66)	%	VMSS Grades								χ^2	p-value
			0 No pain		1 Mild		2 Moderate		3 Severe			
			N	%	N	%	N	%	N	%		
Age At First Menarche												
<12 Years	20	30.3	0	0	7	10.6	8	12.1	5	7.6	13.06	0.15
12-13 Years	34	51.5	2	3.0	16	24.2	13	19.6	3	4.5		
14-15 Years	10	15.1	1	1.5	8	12.1	0	0	1	1.5		
>15 Years	02	3.1	0	0	2	3.0	0	0	0	0		
Duration Of Menstruation												
<7 DYAS	63	95.4	3	4.5	33	50	18	27.2	19	28.7	6.73	0.08
>7 DAYS	3	45.4	0	0	0	0	3	4.5	0	0		
Length Of Menstrual Cycle												
22-28	11	16.6	1	1.5	8	12.1	1	1.5	1	1.5	8.14	0.22
29-35	50	75.5	2	3.0	20	30.3	21	31.8	8	12.1		
>35	5	7.5	0	0	4	6.0	1	1.5	0	0		
No Of Sanitary Napkins Used Per Day												
<2	16	24.2	0	0	4	6.1	10	15.1	2	3.0	8.60	0.19
2-3	48	72.7	3	4.5	26	39.3	12	18.1	7	10.6		
4-5	2	3.0	0	0	1	1.5	1	1.5	0	0		
>5	0	0	0	0	0	0	0	0	0	0		

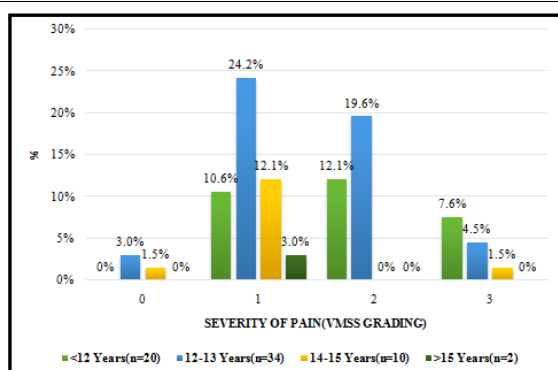


Figure 1: Relationship between menstrual characteristics age at first menarche and severity of dysmenorrhea.

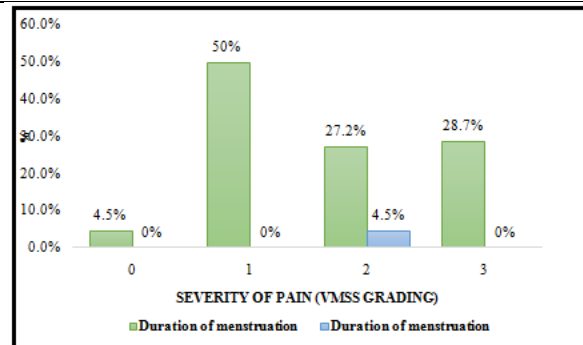


Figure 2: Relationship between menstrual characteristics duration of menstruation and severity of dysmenorrhea.





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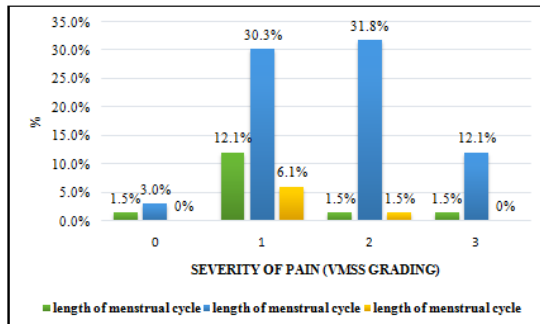


Figure 3: Relationship between menstrual characteristics length of menstrual cycle and severity of dysmenorrhea.

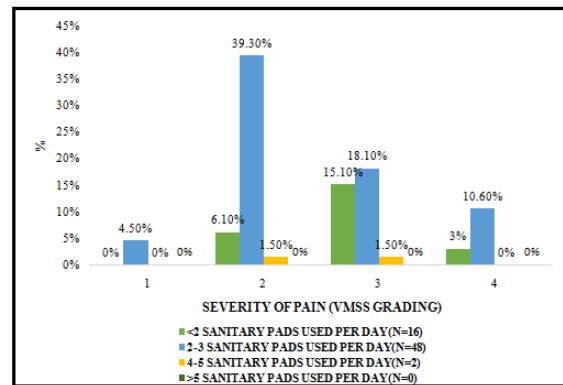


Figure 4: Relationship between menstrual characteristics no of sanitary pads used per day and severity of dysmenorrhea.





Exploring Marketing Strategies for Fertilizer Adoption in Developing Countries : A Secondary Data Perspective

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ABSTRACT

Fertilizer companies play a pivotal role in the agricultural sector, especially in developing countries where food security is a major concern. The challenge for these companies is not only in producing efficient and environmentally sustainable fertilizers but also in marketing their products effectively to farmers, who often face economic, educational, and logistical barriers. This paper explores the marketing strategies adopted by fertilizer companies in developing countries, focusing on their effectiveness, adaptability, and sustainability. By reviewing international literature, we analyze key marketing approaches such as pricing strategies, distribution channels, promotional activities, and product innovation. The study aims to understand how these strategies impact both the companies and their target market, which is largely made up of small-scale and resource-poor farmers. Our analysis provides insights into potential improvements in fertilizer marketing that can support agricultural productivity, economic growth, and environmental sustainability in developing regions.

Keywords: Agriculture, Environment, Marketing strategy, Fertilizer, Developing country etc.





INTRODUCTION

Agriculture is the backbone of many developing economies, accounting for a significant portion of their GDP and providing livelihoods for the majority of their populations. The role of fertilizers in enhancing agricultural productivity cannot be understated, particularly in regions where soil fertility is low and farming practices are often rudimentary. Despite the recognized importance of fertilizers, their adoption and usage rates in many developing countries remain suboptimal.

Fertilizer companies face unique challenges in marketing their products in developing countries. These challenges include limited farmer awareness, infrastructural deficits, low purchasing power, and volatile political and economic conditions. As such, fertilizer companies must adopt tailored marketing strategies that address these specific hurdles. The purpose of this study is to explore and analyze the various marketing strategies employed by fertilizer companies in developing countries and to evaluate their effectiveness in ensuring market penetration and sustained product usage.

The study focuses on the following key aspects:

- Pricing strategies and their adaptability to the economic conditions of small land holder farmers.
- Distribution channels and how they overcome infrastructural challenges.
- Promotional strategies that educate farmers and create awareness about the benefits and proper use of fertilizers.
- Product innovation that takes into account environmental sustainability and localized agricultural needs.

Objectives of the Study

The primary objectives of this study are:

- To examine the marketing strategies adopted by fertilizer companies in developing countries.
- To evaluate the effectiveness of these strategies in improving fertilizer usage among farmers.
- To identify the challenges faced by fertilizer companies in implementing their marketing strategies.
- To provide recommendations for optimizing marketing efforts to enhance agricultural productivity in developing countries.
- To assess the role of government policies and international cooperation in supporting fertilizer marketing strategies.

Hypothesis

This study is based on the following hypotheses:

- H1: Marketing strategies adopted by fertilizer companies in developing countries significantly influence fertilizer adoption rates among farmers.
- H2: Pricing strategies tailored to the economic capacities of smallholder farmers lead to higher sales and market penetration.
- H3: Effective promotional strategies, particularly those focused on farmer education, result in better utilization of fertilizers and improved crop yields.
- H4: Government policies and partnerships with international organizations enhance the marketing effectiveness of fertilizer companies in developing countries.

Evolution of Marketing Strategy

evolution of marketing strategies employed by fertilizer companies in developing countries, focusing on how these strategies have adapted to overcome the challenges and it reflecting the development of marketing approaches over time.

- Early Marketing Approaches in Developing Countries (Pre-1990)** :In the early stages of fertilizer marketing in developing countries, companies primarily relied on government-led initiatives. Before the 1990s, fertilizer





markets were heavily regulated, with many governments in Africa, Asia, and Latin America controlling production, distribution, and pricing. The primary aim of these interventions was to increase agricultural productivity and ensure food security. For instance, in India, the Green Revolution of the 1960s and 1970s played a significant role in boosting fertilizer use through government subsidies and guaranteed pricing mechanisms (Pingali & Rosegrant, 1998). However, these early interventions often led to inefficiencies. Studies by Jayne et al. (2003) highlight how state-run fertilizer programs in Africa resulted in market distortions, poor distribution networks, and reduced incentives for private-sector investment. The reliance on government-controlled distribution channels meant that fertilizers were not always accessible to the farmers who needed them the most, particularly those in remote rural areas.

- ii. **Shift Towards Liberalization and Market-Driven Approaches (1990s)** :By the 1990s, many developing countries began shifting away from state-controlled fertilizer markets towards market-driven approaches, prompted by structural adjustment programs advocated by the World Bank and International Monetary Fund (IMF). Fertilizer companies, particularly in Africa and South Asia, started to play a more significant role in marketing and distribution. The liberalization of the fertilizer sector was seen as a means to increase competition, improve distribution, and reduce government fiscal burdens (Smaling & Braun, 1996). This shift led to the emergence of private-sector-led marketing strategies, where companies adopted competitive pricing models, direct distribution networks, and promotional campaigns to educate farmers. A key study by Wanzala et al. (2001) discusses how the liberalization of the fertilizer market in Kenya resulted in an increase in private-sector investment and improved access to fertilizers in remote areas. The study found that private companies began to partner with local agro-dealers to extend their distribution networks and reach smallholder farmers more effectively. However, liberalization also had its challenges. Several studies, such as those by Kelly et al. (2003), reported that while liberalization improved access in some regions, it also led to higher fertilizer prices due to the removal of government subsidies. As a result, fertilizer affordability remained a significant barrier for many smallholder farmers, particularly in Sub-Saharan Africa.
- iii. **The Rise of Public-Private Partnerships (2000s)**: In the 2000s, public-private partnerships (PPPs) emerged as a key strategy for improving fertilizer marketing in developing countries. Governments, recognizing the limitations of both fully state-controlled and fully liberalized markets, began collaborating with private-sector companies to develop more sustainable and inclusive marketing models. PPPs aimed to combine the efficiency of the private sector with the regulatory oversight and financial support of governments. A landmark study by Gregory & Bumb (2006) outlines how PPPs were instrumental in improving fertilizer access in Sub-Saharan Africa. The African Fertilizer Summit of 2006, which brought together governments, international organizations, and private companies, emphasized the importance of collaborative efforts to increase fertilizer use. As a result, several countries, including Ethiopia and Tanzania, launched PPP initiatives to strengthen fertilizer distribution networks and provide farmers with access to credit. According to the African Fertilizer and Agribusiness Partnership (AFAP), PPPs also enabled companies to adopt more innovative marketing strategies. For example, the introduction of fertilizer voucher systems in countries like Nigeria and Malawi allowed farmers to purchase fertilizers at subsidized prices, while private companies handled distribution and marketing (Dorward et al., 2008). This approach increased fertilizer use among smallholder farmers and improved the profitability of fertilizer companies.
- iv. **Technological Innovations in Marketing (2010s)**: The 2010s saw significant technological advancements that transformed fertilizer marketing in developing countries. Fertilizer companies began leveraging mobile technology and digital platforms to improve distribution, enhance farmer education, and increase transparency in transactions. The widespread adoption of mobile phones in regions like East Africa enabled companies to reach farmers directly through mobile-based marketing and distribution channels. Baumüller (2015) highlights how mobile platforms like Kenya's M-Pesa allowed fertilizer companies to offer digital payment solutions, reducing the need for farmers to travel long distances to purchase fertilizers. Mobile platforms also facilitated the delivery of educational content to farmers, helping them make informed decisions about fertilizer use. Similarly, in countries like Ghana and Tanzania, radio and SMS-based campaigns were used to promote fertilizers and educate farmers on best agricultural practices (Aker, 2011). Technological innovation also extended to product development. Companies began offering fertilizers tailored to specific crops and soil





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conditions, making their products more relevant to local agricultural needs. This shift towards customized fertilizers was supported by research from the International Fertilizer Development Center (IFDC), which emphasized the importance of developing fertilizers that addressed the unique soil deficiencies in different regions (Henao & Baanante, 2006).

- v. **Sustainability and Environmentally-Friendly Fertilizers (2020s):** In recent years, the global focus on sustainability and environmental protection has influenced the marketing strategies of fertilizer companies in developing countries. Companies are increasingly adopting marketing strategies that highlight the environmental benefits of their products. For example, the rise of slow-release and organic fertilizers has provided companies with an opportunity to differentiate themselves in a competitive market while addressing environmental concerns. A study by the International Fertilizer Association (IFA) (2020) emphasizes the growing demand for environmentally-friendly fertilizers in regions like Latin America and Southeast Asia. Fertilizer companies have responded by investing in the development of bio-based fertilizers, which offer lower environmental risks compared to traditional chemical fertilizers. Marketing campaigns now frequently emphasize not only the productivity benefits of fertilizers but also their role in promoting sustainable agricultural practices (Goyal *et al.*, 2020).
- vi. **Current Trends and Future Directions (2020s Onwards):** As of the 2020s, fertilizer companies in developing countries continue to refine their marketing strategies to respond to emerging trends such as digital agriculture, climate change, and evolving consumer preferences. The COVID-19 pandemic further accelerated the adoption of digital tools in fertilizer marketing, as companies increasingly used online platforms to engage with farmers and facilitate product delivery. Studies such as those by Duflo *et al.* (2021) highlight the need for fertilizer companies to focus on inclusive marketing strategies that reach marginalized farmer groups, particularly women and young people. There is also growing recognition of the need for holistic marketing approaches that integrate product innovation, sustainability, and digital tools to meet the complex needs of smallholder farmers in developing countries.

LITERATURE REVIEW

Overview of Fertilizer Marketing in Developing Countries

Fertilizer marketing in developing countries is shaped by complex socioeconomic and environmental factors. Smallholder farmers, who form the bulk of the agricultural workforce in regions like Sub-Saharan Africa, South Asia, and Latin America, often face significant barriers to accessing fertilizers. According to the International Fertilizer Association (IFA), only 10% of farmers in low-income countries use fertilizers regularly, compared to over 60% in high-income countries. Fertilizer companies need to address these barriers through tailored marketing strategies that account for local realities. For instance, a report by the African Fertilizer and Agribusiness Partnership (AFAP) highlights how partnerships between governments, private companies, and local distributors have helped improve fertilizer access in countries like Kenya and Tanzania. However, the AFAP also notes that adoption remains low due to high prices and limited farmer education, underscoring the need for integrated marketing strategies that combine pricing, distribution, and promotional efforts. Marketing fertilizers in developing countries poses several unique challenges. In regions such as Sub-Saharan Africa and South Asia, a significant portion of the population relies on agriculture for their livelihood. However, due to limited access to capital, information, and technology, farmers often underuse fertilizers or misuse them, leading to low agricultural productivity. Fertilizer companies, therefore, need to adopt marketing strategies that not only promote their products but also educate the farming community on their correct use. In India, for example, the government has played a pivotal role in regulating fertilizer prices and providing subsidies to make fertilizers more affordable to smallholder farmers. Similarly, in countries like Kenya and Ethiopia, public-private partnerships have been critical in improving the distribution and availability of fertilizers. Studies show that when farmers receive proper training on fertilizer use, crop yields increase significantly, which in turn encourages further investment in fertilizers. For example, in Bangladesh, fertilizer companies offer both premium and budget products to cater to different segments of the farming population.



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- i. **Pricing Strategies:** Pricing strategies in the fertilizer industry are particularly important in developing countries due to the low purchasing power of most farmers. Many fertilizer companies in countries like Nigeria, India, and Bangladesh have adopted tiered pricing strategies that offer different fertilizer products at various price points, depending on the economic capacity of their target market. Subsidized pricing models, supported by government policies, have also proven effective in improving fertilizer adoption. Research by Pingali and Rose grant (1998) found that governments in Southeast Asia that subsidized fertilizers saw a 30% increase in fertilizer use and a corresponding increase in food production. However, subsidized pricing can also have negative consequences, as evidenced by reports from Ghana and Zambia, where poorly implemented subsidy programs led to market distortions and a decline in private-sector participation in the fertilizer market (Jayne & Rashid, 2013). It is therefore essential that pricing strategies balance affordability for farmers with long-term market sustainability.
- ii. **Distribution Channels:** Distribution remains one of the greatest challenges for fertilizer companies in developing countries. Poor infrastructure, particularly in rural areas, makes it difficult for companies to reach smallholder farmers. Many companies have responded to this challenge by developing innovative distribution channels. In some regions of Africa, for example, fertilizer companies partner with local agro-dealers who act as intermediaries between the company and the farmer. This model has been particularly successful in countries like Tanzania and Malawi, where agro-dealers provide not only fertilizers but also advice on their usage. Mobile technology has also emerged as a critical tool in fertilizer distribution. In Kenya, companies have adopted mobile payment systems like M-Pesa to facilitate the purchase and delivery of fertilizers, reducing the need for farmers to travel long distances to buy inputs (Baumüller, 2015).
- iii. **Promotional Strategies:** Promotional strategies are keys to increasing fertilizer awareness and adoption among farmers, particularly in regions where illiteracy and lack of formal education are prevalent. Fertilizer companies in India, for example, have used village-level demonstrations and farmer field schools to promote their products. These programs show farmers firsthand the benefits of using fertilizers and provide them with the knowledge to apply them correctly. A study by Duflo, Kremer, and Robinson (2008) found that farmers who attended such programs were significantly more likely to use fertilizers correctly, leading to increased crop yields. Radio and mobile phone messaging have also been effective promotional tools, especially in countries where internet access is limited. In Tanzania, for example, radio programs that provide agricultural advice have been shown to increase farmers' knowledge of fertilizers, leading to higher adoption rates. Radio and mobile-based promotion are also widely used in Africa, where literacy levels may be low but mobile phone penetration is high. Secondary data from Tanzania's agricultural development programs show that radio broadcasts and SMS-based campaigns have successfully increased farmers' awareness and adoption of fertilizers (Baumüller, 2015).
- iv. **Product Innovation and Sustainability:** In recent years, fertilizer companies have begun to focus on developing products that are not only effective but also environmentally sustainable. In countries like Brazil and India, where concerns over soil degradation and environmental pollution are growing, companies have started offering slow-release and organic fertilizers that minimize harmful environmental impacts. According to the International Fertilizer Association (IFA), the development of bio-based fertilizers in Latin America has been a key factor in promoting sustainable agricultural practices while maintaining productivity. The literature suggests that product innovation is crucial for addressing the specific agricultural needs of developing countries. In Southeast Asia, for instance, fertilizer companies have created region-specific products that cater to different soil types and crop requirements, leading to improved agricultural outcomes. In India, several companies have launched organic fertilizer lines to cater to the rising demand for sustainable agricultural inputs. A 2018 study by the IFA showed that product diversification, especially the introduction of micronutrient-enriched fertilizers, has helped companies penetrate new markets and address specific soil deficiencies prevalent in different regions.
- v. **Role of Government and International Partnerships:** Government policies and international partnerships play a significant role in supporting fertilizer marketing strategies in developing countries. Many governments provide subsidies and tax incentives to encourage the use of fertilizers, while international organizations like the World Bank and the Food and Agriculture Organization (FAO) offer technical and financial assistance. In West Africa, for example, the Alliance for a Green Revolution in Africa (AGRA) has worked with local governments and private companies to improve fertilizer accessibility and affordability. However, as highlighted by Omamo



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(2003), government interventions must be carefully designed to avoid unintended consequences such as market distortions and over-reliance on subsidies. Successful government involvement requires a balance between supporting farmers and ensuring that the fertilizer market remains competitive and sustainable. However, some studies have pointed to the risks of government intervention, particularly when subsidies are poorly managed. A report by the International Food Policy Research Institute (IFPRI) notes that in some African countries, government-led fertilizer programs have crowded out private-sector participation, leading to inefficiencies and reduced market competition.

Suggestions

Based on the analysis of secondary data, the following suggestions are made for improving the marketing strategies of fertilizer companies in developing countries:

- i. **Customized Pricing Models:** Companies should explore flexible pricing strategies, such as offering smaller package sizes or pay-as-you-go options, to make fertilizers more affordable for low-income farmers or farmers group.
- ii. **Strengthening Distribution Networks:** Government can collaborating with local agro-dealers and leveraging digital platforms for direct sales can help overcome distribution challenges in remote areas.
- iii. **Farmer Education and Promotion:** Companies should invest in farmer education programs, including demonstration plots and mobile-based learning platforms, to promote proper fertilizer usage.
- iv. **Sustainable Product Innovation:** Fertilizer companies should focus on developing environmentally sustainable products, such as bio-based and slow-release fertilizers, to address growing concerns about soil health and environmental degradation.
- v. **Public-Private Partnerships:** Governments and international organizations should continue to support PPPs that enhance fertilizer access and promote agricultural development, while ensuring that subsidy programs are managed efficiently to avoid market distortions.

CONCLUSION

Fertilizer companies in developing countries operate in challenging environments characterized by limited infrastructure, low farmer literacy, and economic constraints. This study highlights the importance of adopting marketing strategies that are tailored to these unique challenges. Effective pricing, innovative distribution models, targeted promotional activities, and sustainable product development are all critical components of a successful marketing strategy. Additionally, government support and international partnerships are essential for improving market conditions and ensuring that fertilizers reach those who need them most. Future research should focus on evaluating the long-term impacts of these strategies on agricultural productivity and food security in developing countries. By continuing to innovate and adapt, fertilizer companies can play a crucial role in supporting sustainable agricultural development in the world's most vulnerable regions.

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Repurposing of Diabetic Drug to Treat Parkinson 's Disease

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ABSTRACT

The different components of the neurodegenerative disease pathophysiology that are frequently addressed. The Neurodegenerative disorders including pathogenesis are commonly targeted by the individual aspects. Parkinson's disease (PD) and Alzheimer's disease (AD) are two conditions that share many pathological characteristics. These include abnormal toxic protein accumulation, increased inflammation, impaired synaptic function, loss of neurons, increased activation of astrocytes, and possibly insulin resistance. preclinical and early clinical research remarkable clinical potential have displayed by the glucagon like peptide 1 receptor agonist. The toxic protein aggregation, inflammation and apoptosis can be reduced by targeting brain incretin receptors. Furthermore, it is critical to understand how the course of neuro degeneration in a difficult disease like Parkinson's disease might be influenced by a common and manageable condition like diabetes. The current body of research on the relationship between diabetes and Parkinson's disease, as well as the potential effects of currently available antidiabetic drugs on the course and severity of Parkinsonism, with an emphasis on agonists of the glucagon-like peptide-1 receptor. Repurposing several anti-diabetic drugs for the treatment of Parkinson's disease (PD) has showed early promise in clinical studies, indicating that the impact of type 2 diabetes (T2D) on the pathogenesis of PD may be controllable. Despite a wealth of evidence linking the pathophysiology of both T2D and PD to processes like insulin signaling, mitochondrial function, autophagy, and inflammation, the main goal of this review is to highlight the evidence that T2D-associated dysregulation of these pathways occurs in the brain as well as the periphery, and how this may contribute to neuro degeneration in PD. The prevalence of chronic illnesses like Parkinson's disease (PD) has skyrocketed globally in recent years. Type 2 diabetes mellitus (T2DM) has been implicated as a potential risk factor for Parkinson's disease (PD), and concomitant T2DM may exacerbate PD symptoms and hasten neuro degeneration. Numerous research on the therapeutic potential of T2DM medications against PD have been motivated by the same pathogenic pathways shared by PD and T2DM; among these, agonist of the glucagon-like peptide-1 receptor (GLP-

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1R)are interesting possibilities. Parkinson's disease (PD), which is characterized by dopaminergic degradation and aberrant movements, is the second most common age-related hypokinetic illness. The majority of Parkinson's disease patients have dopaminergic degeneration in the basal ganglia. DPP4 inhibitors are often used to treat diabetes and are currently undergoing testing to determine their efficacy in neurodegenerative disorders. In numerous preclinical and clinical PD trials, DPP4 inhibitors have been shown to prevent neuronal degeneration and enhance motor capabilities.

Keywords

Alzheimer's disease; Antidiabetic; Glucagon-like-peptide-1; Incretin; Insulin; Parkinson's disease, DPP4 inhibitors; Dopamine; Neuroinflammation; Oxidative stress; Parkinson's disease; molecular mechanisms; type 2 diabetes, antidiabetic; diabetes mellitus; dopamine; exenatide; insulin; neurodegeneration; neuroinflammation; repurposing,

INTRODUCTION

A variety of crippling illnesses that predominantly impact the human central nervous system's (CNS) neurons are together referred to as neurodegenerative diseases. Mental dysfunction or impaired mobility (ataxia) may arise from the increasing nerve cell loss and degeneration. With over 50 million instances occurring globally, AD accounts for 60–70% of dementia cases worldwide. The connection between metabolic and neurodegenerative diseases is becoming more widely acknowledged by the research community. Abnormalities in insulin signaling have been identified as a characteristic of older people with type 2 diabetes (T2DM) and pre-diabetes; same abnormalities have also been seen in AD and PD. T2DM additionally seems to have a negative impact on the severity of symptoms and the course of the disease. As an illustration, having diabetes before to Parkinson's disease (PD) raises the chance of experiencing increased severity of motor symptoms, as measured by the Horgan and Yahr staging and the Unified Parkinson's Disease rating scale, as well as a more negative impact on day-to-day activities As shown in Fig. 1, the major insulin receptor signaling networks play a critical role in supporting neuronal development and differentiation, cell metabolism, synaptic plasticity, and neuroprotection. AKT phosphorylation is linked to AD progression and cognitive dysfunction. Function of neuronal insulin signaling (Fig. 1). Illustration of activation of the second messenger pathway. medications that fight diabetes for neurological conditions Table 1. Trial setup and results of antidiabetic drug clinical studies in AD and PD populations. Both Alzheimer's disease (AD) and Parkinson's disease (PD) are complex illnesses that include multiple pathological processes, including aberrant buildup of toxic proteins, inflammation, loss of neurons, astrocyte activation, and even insulin resistance. Given the biological similarities between diabetes mellitus (DM) and neurodegenerative disorders (AD and PD), anti-diabetic medications hold significant promise as a treatment approach

Table 1 lists the trial design and results of clinical studies on antidiabetic medications in AD and PD populations.

Another substance made using recombinant DNA technology is dulaglutide, which is appropriate for injection once a week. (GIP and GLP-1 receptor agonist structures is shown in Fig. 2). Figure 2 shows the structures of GIP, GLP-1, and native human equivalents, such as tirzepatide, an agonist of the dual GLP-1/GLP receptor and exenatide, lixisenatide, liraglutide, albiglutide, semaglutide, and dulaglutide. Abbreviations: GLP-1 (glucagon-like peptide-1) and GIP (gastric inhibitory polypeptide). References for the structure: GLP-1 CID 90488821 URL It's feasible that dysregulated insulin transmission in the brain can be compensated for by GLP-1 receptor activation. The GLP-1 receptor, a member of the G protein-coupled receptor family, is how GLP-1 works. The best way to characterize pancreatic beta cells are the site of GLP-1 signaling, where activation of the receptor increases insulin production. Several other pathways, such as Akt/PKB and PI3K/MAPK, are improved after receptor stimulation. Numerous beneficial benefits, including the induction of anti-inflammatory signalling, the reduction of oxidative stress, the enhancement of gene transcription, and the regulation of autophagy, are associated with GLP-1 signalling. To pinpoint minute variations in the intracellular signalling pathways-which could vary depending on a number of variables, including the brain region-more investigation is needed. For more on GLP-1 communication throughout the brain, see Fig. 3. Figure 3. The brain's GLP-1 signalling pathway. influence of downstream signalling cascades on



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neuroprotection. Abbreviations: GLP-1 (glucagon-like peptide-1), ATP (adenosine triphosphate), and Glucagon like peptide -1 receptor, abbreviated GLP-1R peripheral tissues such the pancreas, heart, gastrointestinal track, adipose tissue, kidney, and muscles, as well as islet alpha and beta cells express GLP-1 receptors. GLP-1 is expressed so widely that it is connected to many different systems and functions. GLP-1 influences lipogenic and lipolytic activities and enhances adipose tissue's absorption of glucose. increases muscular glucose oxidation and glycogen production while decreasing albumin excretion and natriuresis in the kidney. Through its effect on the heart, GLP-1 increases heart rate and decreases systolic blood pressure, hence promoting cardio protection. Preclinical data indicates that GLP-1 receptor agonists hold great promise for preventing the progression of dementia. Eight seven-month-old APP/PS1 mice showed less memory loss after receiving weekly liraglutide therapy. This effect was accompanied in the hippocampus by a reduction in synaptic loss and maintenance of synaptic plasticity. Liraglutide successfully mitigated both mitochondrial dysfunction and neuronal death via the cAMP/PKA pathway in astrocytes treated with A β . One possible explanation for the success of liraglutide treatment could be the restoration of insulin signalling in the brain. Liraglutide inhibits the loss of insulin receptors in β -amyloid oligomer-induced models in non-human primates as well as mice. A number of GLP-1 receptor agonists, other than liraglutide Preclinical models collectively show that GLP-1 receptor agonists may affect a number of important pathological characteristics of AD, such as inhibiting the development of amyloid plaque, lowering inflammation, boosting neurogenesis, and improving cognitive function. Increasing data indicates that agonist of GLP-1 receptors could an impact on tau pathology, which is encouraging. Exenatide injections have shown promise in Alzheimer's disease (AD) preclinical models, as they were shown to diminish tau hyper phosphorylation in a rat model of type 2 diabetes fed a high -fat diet. In male rats, Exenatide significantly decreased β -amyloid in the prefrontal cortex and hippocampal regions and improved memory impairments. Exenatide also raised Akt and inhibited mitochondrial toxicity. In a Liraglutide pilot study, randomly assigned groups of 38 AD patients were given either active medication (n=18) or twenty placebo recipients. Eleven individuals were allocated at random to get exenatide twice daily, whereas ten patients received a placebo in a pilot study lasting eighteen months that evaluated exenatides effects on AD.

Therefore, exenatide may be able to lessen brain amyloidosis, which calls for more research in AD. Premature trial termination reduced the statistical power to get the intended results. According to a preliminary examination of REWIND that assessed cognitive performance at the start and end of the study, patients on dulaglutide had a 14% lower probability of acquiring meaningful cognitive impairment. Furthermore, in 15,820 T2DM individuals using semaglutide or liraglutide treatment, the dementia diagnosis hazard ratio was to be determined by a combined post hoc analysis of three trials examining cardiovascular outcomes. Repurposing agonist of the GLP-1 receptor for AD has promise in preclinical and early clinical evaluation when combined, as seen by the entry of semaglutide into a comprehensive phase 3 assessment of people with early AD. When contrasting AD preclinical and clinical research that evaluate the effectiveness of antidiabetic medications, it is crucial to take note of significant limitations. Models of transgenic mice based on mutations causing the family form of AD are used in most preclinical research, even though over 99% of AD patients have the sporadic form of the illness. The PI3K-AKT signalling pathway may be modulated by GLP-1 to have neuroprotective effects on Parkinson's disease. The beneficial benefits against Parkinson's disease pathology may also be explained by c-AMP is up regulated following GLP-1 receptor activation. Even though over 99% of AD patients have transgenic mouse models based on mutations that create the familial form of the disease are used in most preclinical studies to study it's sporadic form of the disease. GLP-1 may have neuroprotective benefits on Parkinson's disease (PD) by modulating the PI3K-AKT signalling pathway. GLP-1 receptor activation-induced up regulation of c-AMP may also contribute to the protective benefits against Parkinson's disease pathogenesis. Additionally, a protective effect of GLP-1 has been suggested to play a part in the BBB's upkeep. Exenatide was generally well tolerated and safe by the subjects. At 12 months, the Movement Disorders Society Unified Parkinson's Disease Rating Scale (MDS-UPDRS) showed improved motor performance in exenatide-treated participants, with a mean improvement of 2.7 points, compared to a mean drop of 2.2 points in controls. Two months after therapy ended, despite stopping medication, improvements in motor function continued condition. Because of the tiny sample size and single-blind technique, the data from Aviles-Olmos et al., although positive, should not be taken as evidence of a treatment-modifying impact. Athauda et al. evaluated the impact of exenatide in sixty-two individuals suffering from idiopathic Parkinson's disease (PD) in a bigger phase II trial. It is becoming more



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widely acknowledged that evaluating neuronal-derived extracellular vesicles in vivo offers a viable way to uncover the mechanism underlying centrally active medications. It has been shown that enatide therapy increases the tyrosine phosphorylation of IRS-1; this result was linked to modifications in Akt and m-TOR, two downstream effectors. GLP-1 receptor agonists present a potential therapeutic option for symptoms related to cognition, movement, and non-motion. Two months after stopping therapy, gains were maintained in motor function while without talking medication condition. Despite encouraging results, the study by Aviles-Olmos et al.'s small sample size and single-blind methodology suggest that are data should not be interpreted as proof of a disease-modifying impact. Athauda et al. recruited 62 individuals with idiopathic Parkinson's disease (PD) in a bigger phase II experiment to assess the effects of exenatide. An increasingly popular approach to elucidate the mechanism of centrally acting medicines is the evaluation of neuronally generated extracellular vesicles in vivo. Treatment with enatide was shown to boost IRS-1 tyrosine phosphorylation, an outcome that was linked to modifications in Akt and m-TOR, two downstream effectors. An encouraging tactic for reducing symptoms that are non – motor, motor , and cognitive is the use of GLP-1 receptor agonists. Many interesting candidates that target pathways like GIP, insulin signaling, and GLP-1 may all have neuroprotective properties are going through late-stage clinical investigation. SGLT2 inhibitors are a class of approved medications for type 2 diabetes that decrease blood sugar levels by preventing the kidney's SGLT2 from reabsorbing glucose. The scientists showed that SGLT2 inhibitor therapy could enhance memory and learning while lowering amyloid pathology and brain atrophy. Moreover, SGLT2 inhibitor-dispensed patients had a 20% smaller connection with dementia risk than DPP-IV inhibitor-dispensed participants among 106,903 DM individuals.

Using empagliflozin for 14 days enhanced brain signaling pathways (IRS-1/Akt) and reduced glutamate levels in 21 non-diabetics 55 years of age or older. Therefore, SGLT2 inhibitors are a prospective treatment option for the glutamate excitotoxicity and deficiencies in brain insulin signaling seen in AD. The effectiveness of combining regular intranasal insulin with empagliflozin in patients with amnesic MCI or early AD is now being studied clinically. Promising possibilities for repurposing in the treatment of AD and PD are anti diabetic drugs. Many interesting candidates that target pathways including GLP-1, GIP, and insulin signaling and may have neuroprotective effects are going through late-stage clinical investigation. GLP-1 receptor. It has been shown that agonist affect defective insulin signaling, lessen inflammation and oxidative stress, and stop the buildup of the distinctively harmful proteins. As a result, promising outcomes from antidiabetic medications, such as GLP-1 receptor agonist, that impact several facets of neurodegeneration in AD and PD require additional phase 3 trials to completely assess their therapeutic efficacy. Future trials should focus on determining the efficacy of other medications that are already used to treat diabetes, such as metformin, PPAR γ agonists, amylin analogs, and PTP1B inhibitors, as they have showed promise in the early phases of evaluate for AD and /or PD. When combined, anti diabetic drugs exhibit remarkable promise in the management of AD/PD and may effect the disease's pathogenesis as well as it's behavioural and cognitive symptoms. In light of this, SGLT2 inhibitors represent a viable treatment option for AD's glutamate excitotoxicity and deficiencies in brain insulin signalling. A clinical trial is being conducted to assess the effectiveness of empagliflozin in combination with regular intranasal insulin in patients suffering from amnesic MCI or early AD. Repurposing anti-diabetic drugs for the treatment of AD and PD shows promise. Late-stage clinical evaluation of several interesting candidates, which target pathways like GLP-1, GIP, and insulin signalling and may have neuroprotective effects, is now underway. GLP-1 receptor agonists have been shown to affect defective insulin signalling, limit the buildup of the distinctive harmful proteins, and lessen oxidative stress and inflammation. Thus, favourable outcomes of anti-diabetic medications, such as GLP-1 receptor agonists, which influence several facets of AD neurodegeneration

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Table 1 lists the trial design and results of clinical studies on antidiabetic medications in AD and PD populations.

DRUG NAME	NO.OF PATIENTS	TRIAL DURATION	DOSAGE & OUTCOMES
GLP-1 analogue liraglutide	38 AD patients (N=18; 20 treatment places	26 week period	With no cognitive benefits,1.8mg taken daily prevented a decrease in cerebral glucose metabolism.
Insulin regular intranasal insulin	240 individuals with AD or amnesic MCL	12months	40lu daily. No cognitive or functional benefit
Metformin	20 people with AD -related MCL or mild dementia	16weeks	Treatment with 100 mg twice a day enhanced capacity for executive function
GLP -1 Analogue exenatide	62 patients with mild Parkinson's disease (N=32 treatment sites	48weeks	Treatment with 2mg once weekly enhanced motor outcomes without affecting cognition
PPAR Agonist pioglitazoe	42 patients (N=21 treatment 21place)with mild AD	25-30mg daily	Both cognition and regional cerebral blood flow in the paternal lobe improved with treatment.



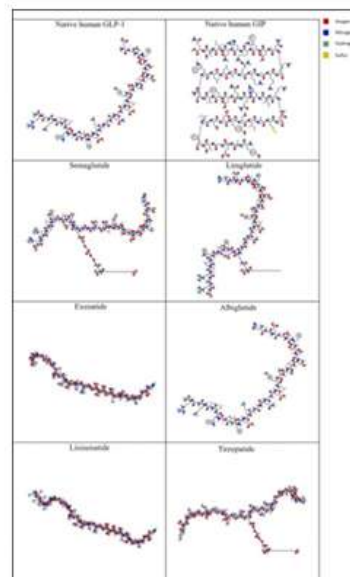
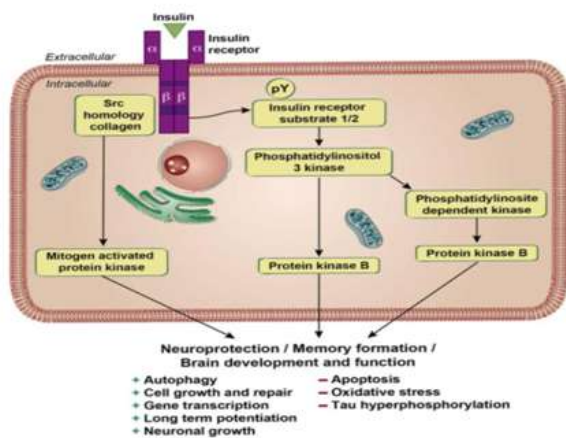


Fig:1 Function of neuronal insulin signaling
<https://images.app.goo.gl/K5ameXJPam95Dmm8A>

Figure 2 shows the structures of GIP, GLP-1
<https://images.app.goo.gl/SLYUe5zLZ9ivtMFt8>

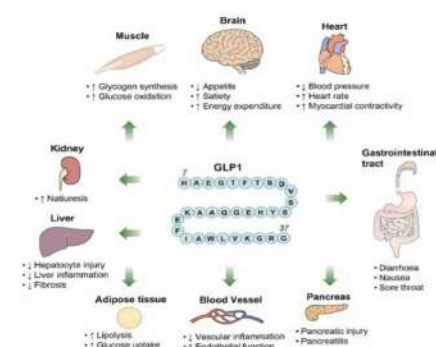
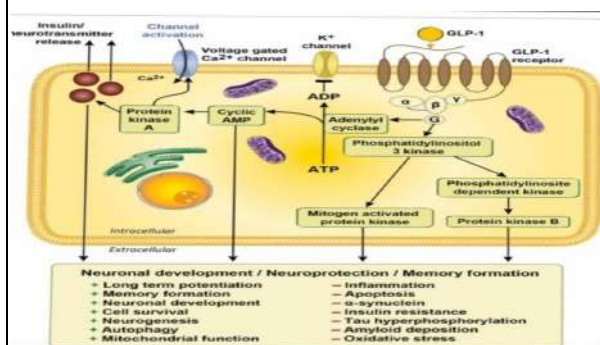


Figure 3. The brain's GLP-1 signalling pathway
<https://images.app.goo.gl/stTopAgsgNQfEc2L>

<https://images.app.goo.gl/h4KPS5UFo3zCbgs>





A Study on Psychological Counselling Needs for Class 9th Students

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ABSTRACT

The Latin verb "adolescere," which meaning "to grow," is the source of the English word "adolescence." Since growth is the fundamental meaning of adolescence, it can be understood to mean a time of extensive growth and change in almost every aspect of a person's life. Adolescence is a time of transition from one stage to the next, and transitions are always associated with certain issues. As the kid develops into a teenager, they face challenges in a variety of areas. Every adolescent has specific needs and demands, which must be met for him to continue growing physically and in other ways. This is because changes, whether viewed positively or negatively, are likely to create an environment of conflict and stress, to which people will react in different ways. Thus, in this present study an attempt has been made to find out the levels of psychological counselling needs for class 9th students. Sample: total of 460 students were used for the study. The "Psychological Counselling Needs Scale," created by Dr. Vijaya Laxmi Chouhan and Mrs. Gunjan Ganotra Arora, was the instrument utilized in the study. Percentiles for interpretation were extracted in order to analyze the data. The study's findings indicate that the overall need for psychological counseling among ninth-grade pupils was "HIGH." Additionally, comparative research indicates that female pupils are on level with their male peers. The study was restricted to Uttar Pradesh's G.B. Nagar District.

Keywords: adolescence, psychological counseling needs, class 9th students.

INTRODUCTION

Worldwide research has shown that psychological counseling is essential for fostering teenage health. However, there is still a lack of discussion in the Asia-Pacific area regarding the specific methods by which psychological counseling can be applied, the best environments in which psychological counseling can function in the context of education, and the effectiveness of such programs in promoting gender equity and equality. The accomplishment of broader educational goals depends on the establishment of psychological counselling programs in schools and the



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integration of gender responsiveness into psychological counseling programs in secondary education. In general, "school counseling" refers to the process of addressing students' needs in a variety of developmental domains, including academic, professional, and personal. Experts concur that comprehensive, preventative, and developmental programs should be the hallmarks of professional school counseling. In the context of counseling, "guidance" refers to a more focused course that aids students in selecting a vocational or career path. The process of assisting people in making life-changing decisions, such selecting a desired lifestyle, is known as guidance. One way that advice and counseling differ from one another is that whilst guiding focuses on assisting people in selecting their values, counseling concentrates on assisting them in making changes. In the context of counseling, "guidance" refers to a more focused course that aids students in selecting a vocational or career path. The process of assisting people in making life-changing decisions, such selecting a desired lifestyle, is known as guidance. In the profession of counseling, "guidance" refers to a more focused trajectory that helps students select a career or occupational path. The process of assisting people in making life-changing decisions, such selecting a desired lifestyle, is known as guidance. One way that advice and counseling differ from one another is that although guidance is more concerned with assisting people in selecting their values, counseling is more concerned with assisting them in making changes. The early stages of adolescence are challenging. Adolescents require direction and sincere help to get through this phase. Adolescents face a variety of difficulties at this point in their lives, and if these difficulties are not overcome, they run the risk of turning into social outcasts. Adolescents' academic performance may suffer as a result of these difficulties. The adage "education is the foundation of any society" comes from the fact that education is one of the elements that determines how advanced a country is. Ironically, because most adolescents are so preoccupied with their social lives, school no longer holds any significance for them. A society can be considered underdeveloped if its teenagers are not motivated by academics. Teenagers must therefore be reintegrated academically into their classes, and counseling programs act as a bridge to better academic accomplishment, which will ultimately contribute to the development of the country.

REVIEW OF RELATED LITERATURE

A thorough review bridges the gaps in the body of available literature and is an essential component of research knowledge. In order to achieve the aforementioned research goal, the study has gathered data from empirical literature and used it to extrapolate pertinent issues for which there are no answers in the collected material. Consequently, the literature has been used to bolster the importance and necessity of the research. This review has been assembled over many years from both Indian and Western literature, and it has been carefully organized with the appropriate designations. In India, the backdrop of significant societal transformation creates a need for psychological counseling (Arulmani, 2007). The last ten years of economic reforms, along with advances in science and technology, have accelerated these developments and transformed lifestyles. The majority of people find that change happens too quickly, which causes major adjustment issues (Rao, 1995). Society is undergoing rapid social and technical change, while values are evolving or being questioned and unpredictability is encroaching on more aspects of daily life. The youngster faces challenges in several areas as he matures into a teenager. Every adolescent has unique needs and issues that require attention from educators, parents, and community elders. This is because, regardless of whether changes are viewed as fortunate or unfavorable, they are likely to create a conflicted and stressful environment that will cause people to react differently. Sarfaraz Ahmad's (2012) study sought to determine how the socio-emotional school environment affected teenage boys' academic performance. In Kanpur city, a sample of 250 male teenagers in their upper secondary years was collected. The study's findings showed a substantial correlation between the socio-emotional school environment and the academic accomplishment of teenage boys and a significant difference between the academic achievement of private and aided higher secondary students. Thus, it was found that one of the key factors influencing teenage boys' academic success is the socioemotional school environment. **Rathee and Thakran (2017)** examined the link between the general well-being and study habits of 80 Haryana senior secondary school students. The authors thought that pupils learned effective study habits in school. The findings demonstrated a beneficial relationship between senior secondary school pupils' overall well-being and their study habits. **A study by Rohit (2018)** conducted to investigate the psychological well-being of 120 higher



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secondary school students, it was discovered that there was no significant difference in psychological well-being depending on their stream of study, which was arts and commerce. There was also no substantial difference between genders in terms of psychological well-being. Kaur (2019) investigated the well-being of 640 Punjabi teenagers enrolled in secondary schools. The findings revealed that approximately 33% of the students have high well-being, approximately 65% have moderate well-being, and the remainder has low well-being. Most boys and girls have an average level of well-being. Urban residents have a high level of well-being, whereas rural residents have a moderate level of well-being. **Harding et al (2019)** conducted a study of the links between stress, protective factors, and psychological well-being among 152 students in New Zealand. Stress was found to be a major predictor of social support, resilience, self-efficacy, and mindfulness. Support, mindfulness, resilience, and family support were all significant predictors of PWB. In 2020, ManishaDhami and Seema Sharma studied 200 teenagers from Government Senior Secondary Schools in the Ludhiana district, 100 of whom lived in urban areas and 100 in rural areas. Additionally, the sample was split evenly across the sexes (100 men and 100 women). Teenagers' psychological counseling needs were evaluated using the Psychological Counseling Needs Scale (Chouhan&Arora, 2009). The findings showed that adolescents' perceptions of their overall psychological counseling needs varied significantly by location. Adolescents in rural areas required additional psychological counseling. The sexes did not differ in any noticeable way.

DELIMITATION OF THE STUDY

The present study was delimited to class 9th students of G.B.Nagar District of Uttar Pradesh, India.

Framework for the analysis**Objectives**

The objectives of the present paper were to test the following:

1. To study psychological counselling needs amongst class 9th students of G.B.Nagar District of Uttar Pradesh.
2. A comparative study of psychological counselling needs between male and female students.

MATERIALS AND METHODOLOGY

Participants: To comply with the objectives, a total of 460 (male & female) students were used as participants in this study.

Tool Used: To assess psychological counselling needs the inventory developed by Dr.VijayaLaxmiChouhan and Mrs.GunjanGanotraArora 'Psychological Counselling Needs Scale' was used. The reliability of the inventory was 0.90.

Statistical Treatment: The collected data was analyzed by finding out percentiles for interpretation.

Analysis and Interpretation

The first objective was to test psychological counseling needs amongst class 9th students. So, the data was analyzed with the help of percentile and the result is given in Table – 1. From table – 1, it is observed that the mean is 77.9 and percentile 91 respectively. When these values are referred to the Established Norms for interpretation, it falls under the psychological counselling needs as 'High', in the hierarchical order of 'Very Low', 'Low', 'Average', 'High', and 'VeryHigh'. Hence, it can be stated that class 9th students of G.B.Nagar district of Uttar Pradesh are need to be counselled taking an account of changing cultural values, family environment, vocational, emotional and sexual development. Primary preventive initiatives are important not only for mental health but also for their intellectual growth which could provide them with adequate support in their changing phase from childhood to adulthood.

The second objective was to compare psychological counselling needs between male and female students. So, the data was analyzed with the help of percentile and the result is given in Table - 2. From the table-2, it is seen that the mean is 78.3(M) and 77.4(F); percent tile is 91(M), and 90 (F) respectively. When, these values are referred to the established norms for interpretation, it falls under psychological counselling needs as 'High' for male as well as for



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female, in the hierarchical order of 'very low', 'low', 'average', 'high', and 'very high'. Therefore, it can be stated that when male and female students are studied they fall under the same level i.e., 'High'. However, if we compare the percentile results, we find that female students and male students are equal in psychological counselling needs.

DISCUSSIONS

The study disseminate that requirement of psychological counseling needs for class 9th students as a whole was 'HIGH', in the G.B.Nagar district of Uttar Pradesh. Further, if we analyze between male and female students, female students have been equal in psychological counselling needs to their peer male students. In this way the responsibilities seems to be equal on daughters and the role that they have in the family and society to the son.

The fact that many people no longer live in empathetic communities united by religious faith and convictions, however, may be the reason why psychological counseling requirements are rated as "high" for both men and women as a whole. They inhabit fractured communities that are isolated from one another and their surroundings. Adolescence is believed to be a time of rapid intellectual, social, psychological, sexual, and moral development, among other rapid developmental stages. Adolescents face challenges in many areas as they mature, which need to be addressed. According to the current study, both male and female students may benefit from psychological counseling. Hence, from the adolescent's point of view for genuine mental health growth, counseling is salient service which needs to be attended for the strengthening of the comprehensive development of class 9th students of the region.

CONCLUSION

In the most basic sense, humans are biological beings. A person's needs and challenges have a significant impact on his development. As is well known, adolescence is a crucial time in a person's life, complete with unique needs and adaption challenges. Every teenager has specific needs and demands, and meeting these is essential to his ongoing physical and other development. Human behavior is mostly determined by basic human wants, such as hunger, thirst, and sex. Common areas that psychological counselling can help fix problems is conduct, depression, apprehension, exasperation, substance abuse, relationship problems, family issues, or a general disappointment with life (Denver Teen Counselling, 2005). Through psychological counselling services, adolescents can be assisted to resolve contrasting problems and endeavour to re-personalize their lives. Infact individual counselling can help them in settling their problems and help the adolescences for untroubled passage to adulthood.

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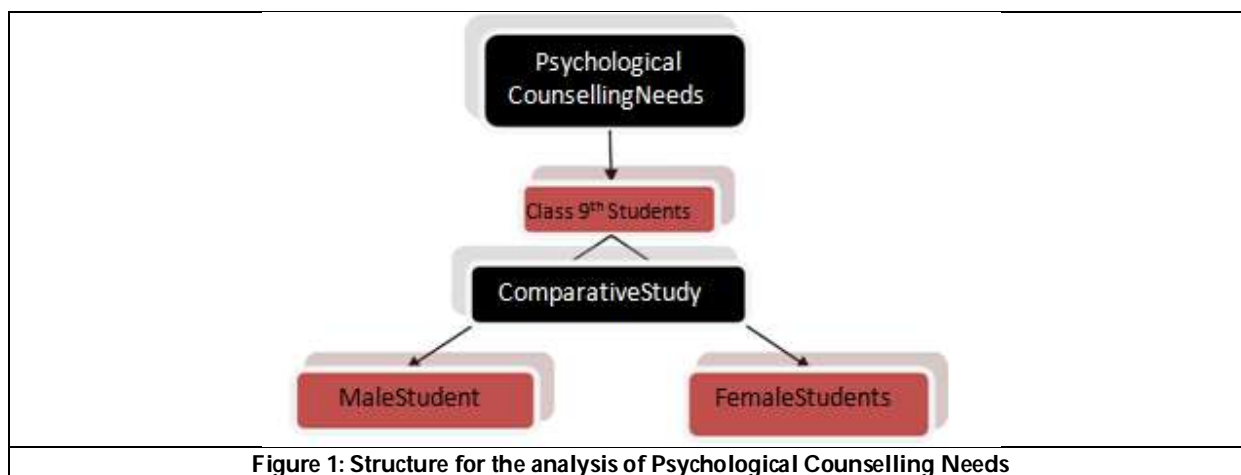
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Table – 1 Result of psychological counseling needs amongst class 9th students

N	Mean	Percentile	Psychological Counselling Needs
460	77.9	91	High

Table – 2 Result of comparative psychological counseling needs between male and female students

N	Mean	Percentile		Psychological Counselling Needs			
Male	Female	Male	Female	Male	Female	Male	Female
246	196	78.3	77.4	91	90	High	High





Food Quality Monitoring

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ABSTRACT

This paper outlines the IoT food-monitoring framework so that it stays fresh, healthy, and unaffected due to the conditions surrounding storage and transportation. The proposed solution analyzes temperature, humidity, and light as these components affect the prices of healthy foods such as fruits and vegetables. The connection of such a sensor to food packaging technology has engraved a clever way of packaging food. These integrated systems can provide reliable information. The system contains heat, moisture, gas sensors, which provide the necessary information to assess the quality of a vegetable or fruit.

Keywords: Food monitoring, IoT, Sensors

INTRODUCTION

Today almost everyone is affected by the food they eat. It is not just unhealthy foods but also vegetables, processed foods, and other foods we eat in our daily lives as it is affected by various factors such as humidity, temperature, and oxygen content that vary from time to time. Improper storage of food items can lead to spoilage. The food monitoring system, therefore, focuses on safe food storage. This program is included in the final sections and contains a variety of electronic sensors, which can read those components that affect food. A control machine can be set to handle each boundary where needed. Quality checking will give the exact amount of new/old food items in the container. The



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information obtained from the test can help the user maintain the quality and quantity of stored food. Therefore, keeping the user up to date about monitoring the quality of some or all of the communication technologies is necessary, because a wireless sensor network is required. Various communication technologies are available these days. These technologies differ from one another in terms of communication distance, data transfer speed, reliability, etc. A communication protocol where a user of this program can access data from any convenient location.

LITERATURE REVIEW

In [1] The Thing speak web service is an open API that hosts various sensors to monitor cloud-level sensed data. It allows data to be ported to MATLAB using a channel ID and API key. Then processing and sending detected data to the Thing speak Cloud using an Arduino board and a Wi-Fi Module. The service can track data value at specific intervals. In [2] The research proposes a multidimensional model-based method for comparing IoT services, followed by density-peaks-based clustering to group similar services. The dynamic service matchmaking, discovery, and replacement algorithms are then implemented. Evaluation tests confirm the effectiveness of these approaches, resulting in encouraging outcomes. China faces food safety challenges due to its dispersed food supply. The pilot A IoT pilot project aims to enhance food supply network integrity and security using modern technologies like service-oriented architecture, global identification, and electronic pedigree. A IoT simplifies food purchasing and supply management by combining fresh vegetable supply chain data, as demonstrated by Lushang Ltd., a Shandong-based food provider, enhancing food safety [3]. This study proposes an innovative IoT architecture that can track agriculture from the field to the supply chain and food processing settings. It suggests using IoT technologies to create a food logistics safety tracking system. Through calculations, the system determines the positioning, production, and safety details of the intended food goods [4]. In [5] The Internet of Things (IoT) is expected to connect 28 billion things by 2020, improving energy efficiency, remote monitoring, and physical asset control. IoT is used in various industries, including healthcare, home appliances, retail, energy, manufacturing, mobility, transportation, logistics, and media. It is used in daily life for door unlocking, card recognition, automatic locks, vehicle detection, toll payment systems, tracking animals, access control, payment systems, contactless smart cards, anti-theft devices, and steering column readers. Sensors anticipate human needs based on context information. This study evaluates three data estimating tools to improve food safety in fully loaded strawberry shipping containers. The results show that applying these strategies lowers commercial costs and sensor count. The absolute inaccuracy between ambient and product temperatures was reduced by 97.14% using eight source sensors and an average error of 0.1°C. Even with one container sensor, a 62% improvement was made. These technologies offer potential for industrial value addition, cold chain operations enhancement, and decreased product loss through more precise shelf life estimations [6].

NODEMCU

Nodemcu is an open-source I firmware that runs on the ESP8266 Wi-Fi SoC based on the ESP-12 module. MQ3 gas sensor. When the concentration of ethanol gas increases as the concentration of this phase increases. It has 4 anchors-analog out, digital out, Vcc, ground. The ground connects to the same soil and the Vcc sensor connects to the standard Vcc. The digital output pin of this sensor was not used to disconnect. The analog output pin is connected to the analog board pin. LDR stands for Light Dependent Resistor. Its main purpose is to receive light. The LDR sensor is a photocell that works on the photoconductivity principle. LDR is connected to the analog pin A1 of the Nodemcu board. DHT-11 temperature sensor. It is also known as the moisture sensor. It consists of two main components - one is the moisture sensor and the other is the heat sensor. Vcc sensor connects to standard Vcc. Similarly, the earth is connected to the place we agree on. D4 board pin connects to the data output pin for this sensor. It has a capacitor as part of the moisture sensor and a thermistor as part of the temperature sensor. IC 4051 is an 8 single multiplexer/demultiplexer used as a digital-controlled analog switch. The device has binary input controls installed and blocking input. Includes low ON impedance and very low on current OFF. Control of analog signals up to the full range of power supply can be achieved. With IC 4051 we can connect up to 8 analog devices to one Nodemcu analog pin. IC 7805: The IC voltage controller maintains the output power at a constant value. The 7805 IC, which is a



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78xx component of a series of equal direct voltages used to maintain such flexibility, is a popular voltage regulator integrated circuit (IC). The xx to 78xx shows the output power provided. The 7805 IC provides 5 volts power supply with conditions for adding a sink.

SOFTWARE

ThingSpeak
Arduino IDE

USE OF SOFTWARE

Enter data into ThingSpeak

Step 1: Register / Login to the ThingSpeak website.

It's easy to just enter your email id and verify your Account.

Step 2: Create a new channel.

Step 3: Enter a name and a field. You can have more fields depending on the sensor number, create more fields such as Light, Temperature, Humidity, MQ3, and LDR.

Step 4: Then Save channel.

Step 5: Obtaining the API key.

Click on the API key tab and look for these two fields. Write the API Key and update the channel feed line.

We need a digital dashboard to monitor and display data uploaded to the Thingspeak server. The digital dashboard used here is Freeboard.io which will display sensor data. The JASON file is used here to display Thingspeak data.

Step 6: Register / Login to Freeboard.io

Step 7: Enter a name and click on the create button.

Step 8: Click on the data creation source and select the type as JSON.

Step 9: Enter the channel name and id.

Step 10: Click add window and select as Gauge.

Step 11: To create widgets fill in the path as shown.

Repeat the same process for light intensity, ethanol gas, and moisture.

PERFORMANCE

This food quality monitoring system should be installed in the grocery store. When the installation is complete, the user needs to connect to the Internet via a Wi-Fi modem. The system will start reading data from integrated sensors - MQ3 sensor and LDR sensor, DHT-11 temperature, and humidity sensor. The DHT11 sensor has a capacitive sensor and a thermistor sensor. The operating voltage of DHT11 is 3.5 to 5.5 V, it can detect temperatures from 0 to 50 ° C and can sense relative humidity from 20 to 95%. Provides real-time heat and humidity at normal times. The DHT11 data pin is used for the first time as input and sends the first signal to it. The first signal starts up by 18 milliseconds and then goes up by 20-40 microseconds, after which it goes down by 80 microseconds and then upwards by 40 microseconds. When the first signal is fully sent the data pin is set to output mode. 5 bytes of data containing heat and humidity readings are transmitted. Except for the 5-byte, the first two bytes are designed for relative humidity, the third and fourth bytes are temperature-sensitive and the last is a checksum byte. When food is spoiled it releases the ethanol gas received by the MQ-3 sensor. The analog power generated by the MQ-3 sensor is equal to the gas filter. Analog output is converted to a digital signal by ADC. The information from all the sensors is given to the board and then converted into wire value. Cable value data is assigned to the LCD for display. The node thread is connected to Esp-8266 to upload data to the Thingspeak server.

BENEFITS

- Better food safety and quality control.
- Real-time making of food.
- IoT network resources to reduce waste, costs, and risks in food storage.





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- Quick and paperless testing will save many hours and user space which helps the user to focus on other things.
- Users will be aware of system malfunctions immediately.
- Extensive data analysis can be done in future analysis.
- Commercial profit increases.

LIMITATIONS

- Security limit exists.
- Sometimes the installation of tools accumulates.
- System failure may occur due to a lack of sudden power outages.
- Cloud infrastructure is less secure and improved so there may be a privacy issue.

APPLICATIONS

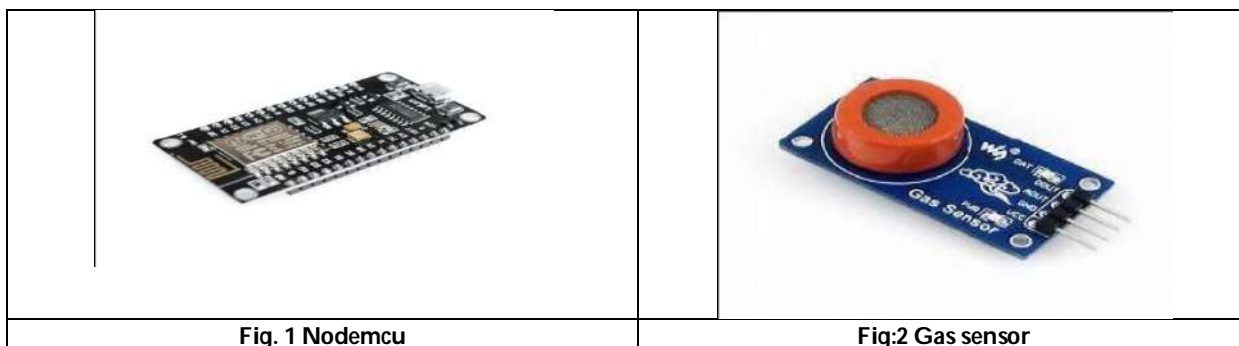
- Monitoring of warehouses
- Cold monitoring of meat and dairy products.

SCOPE

- Live photos and videos can be found on the webcam which will help determine the actual status of the product.
- If the fire is automatically detected the fire extinguisher should light up.
- Multiple sensors can be added to achieve more system parameters.

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Fig:3 LDR sensor

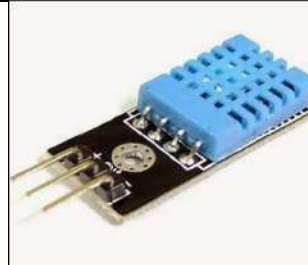


Fig:4 Temperature sensor



Fig:5 Mux/Demux IC 4051

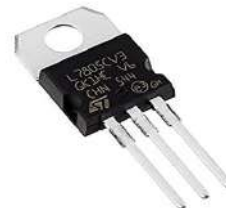


Fig:6 IC 7805

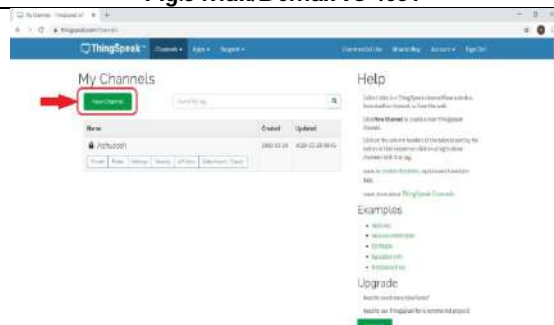


Fig:7 Step 2

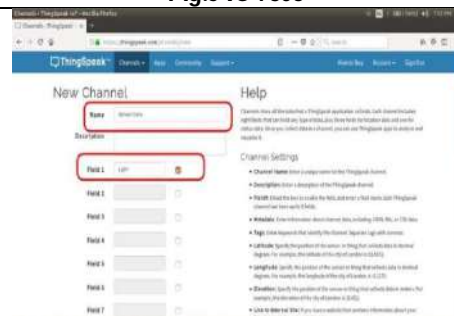


Fig:8 Step 3

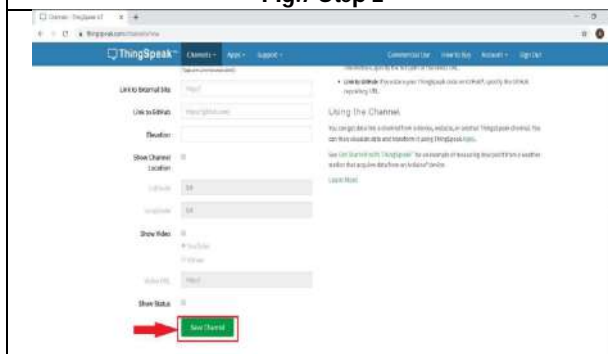


Fig:9 Step 4

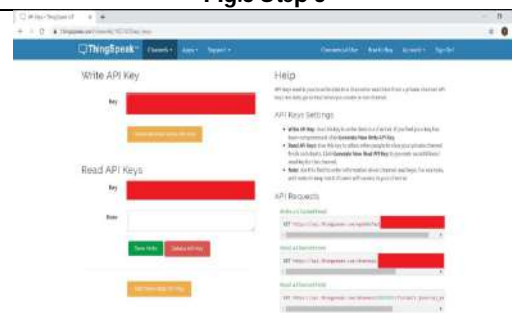


Fig:10 Step 5





<p>Fig: 11 Step 6</p>	<p>Fig: 12 Step 7</p>
<p>Fig:13 Step 8</p>	<p>Fig:14 Step 9</p>
	<pre> graph LR Warehouse --> DHT Warehouse --> LDR Warehouse --> Gas_Sensor DHT --> WODENCU LDR --> WODENCU Gas_Sensor --> WODENCU WODENCU --> Digital_Dashboard WODENCU --> Power_Supply </pre>
<p>Fig: 15 Step 10</p>	<p>Fig:16 Step 11</p>





Energy Assessment and usage Prospect of Renewable Energy Resources at Anandabag Tea Estate

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ABSTRACT

Assam has become famous for housing one of the biggest and most respected tea industries among other states in India, having 100 tea gardens. According to reports, the production and growth of tea led to all other agricultural plantation crops in India. The production and consumption of tea have consistently increased over the years, thus placing it as an important economic pillar in the country. The tea industry, in general, is a highly power-heavy food processing unit that uses both thermal and electrical power ranging from 4.5 to 6.83 kWh. Conventional fuels play the greatest role as a source of energy for different processes. With increasing energy requirements and rising prices of fuel, tea wastage is available in abundance on campus and has been under investigation for controlled utilization to meet high-energy needs. This approach is to help in the production of electrical energy and move towards nonrenewable fuels, thereby lessening costs involved when producing tea. 14.4-63, 8 MJ kg waste material or finished products are used for processes such as withering, drying, grading, and packaging of tea. 30 percent of total costs involves power. 1,352 thousand tons of CO₂ is emitted annually owing to the total fuel use in India's tea industry. This study is based at Anandabag Tea Estate in Assam, India, where the energy used during different manufacturing stages was estimated.

Keywords: Renewal energy, Hydro power plant, Biomass, Wind energy, Solar energy.



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INTRODUCTION

Assam tea is a significant contributor to the global tea production, accounting for almost 15.6% of the world's tea output and 55% of India's total tea production¹⁾. Anandabag Tea Co. Ltd, established in 1893 and incorporated in 1920, has gained a reputation for producing high-quality CTC and Orthodox teas under the brand name "Anandabag," which means "Garden of Happiness." The company has earned worldwide recognition and a loyal customer base in countries like Japan, China, Russia, Iran, Germany, and others. Anandabag Tea Estate has an advanced in-house manufacturing facility in Upper Assam, equipped with HACCP & ISO 22000:2005 standards to produce high-quality CTC and Orthodox teas and package them in vacuum packs²⁾. The company's specialized manufacturing process, managed by a team of experienced professionals and tea tasters, ensures that the natural aroma and colour of Assam CTC tea are maintained, and 100% food grade poly is used for final packaging, ensuring the quality of tea. Electricity and thermal energy are essential requirements for tea plantation and manufacturing processes. Irrigation and tea production machinery require electricity, while thermal energy is needed for withering and drying tea leaves. Major energy used area in tea estate are for processed heating thermal energy, for machine operation electricity, for transportation and plantation petroleum fuel and for domestic purposes both thermal and electrical energy³⁾. To mitigate the energy demand of the tea Estate The tea industry's energy demand is approximately 0.679 kWh of electrical energy and 28.39 MJ of thermal energy per kg of tea⁴⁾. However, natural gas, which constitutes a significant portion of the production cost, is crucial for producing thermal energy. To address the energy and environmental challenges faced by the industry, it is necessary to replace conventional fuels like coal, diesel, and natural gas with renewable, energy-efficient, and eco-friendly production processes⁵⁾. The energy cost around 30% of the total processing of tea costs. Moreover, the total consumption of fuel by the tea industry in India emits 1,352,000 tons of CO₂ annually⁶⁾. Therefore, a considerable amount of care should be taken for the energy factors in the tea industry owing to the energy efficiency and its effects. In tea industry there are possibilities of other sources of energy producing factor, like wind, solar and bio energy. India has ranked 5th in the installed wind capacity. Renewable energy installed in India in 2013 was 28GW, of which wind energy claims nearly 70% with an installed capacity of 19.05GW. Likewise, solar energy can also be a source of power generation, as India is more suitable for solar energy as it receives highest solar insolation. With 300 sunny days, India can generate 600 TW of power⁷⁾. The CO₂ emissions of this type of energy is very small. The average value of annual reduction of CO₂ emission for wind energy system is 600 tons of CO₂/GWH and for solar thermal system 12840 Kg of CO₂/m⁸⁾. Since, Assam has potential to harness both solar and wind energy, after analysis of the previous studies, the feasibility of renewable sources to meet the energy demand required by Anandabag Tea Estate and the challenges faced in its establishment will be assessed through this paper.

Energy requirement in tea plantation of the industry

Tea manufacturing industries heavily rely on energy as a primary resource. The tea production process involves various stages such as seed nursery preparation, cultivation, pruning, and plucking, which consume significant amounts of energy in the form of human labor. However, the most energy-intensive stages of tea production are the post-harvest processes, which include withering, rolling, fermentation, drying, sorting/grading, and packing. Among these, withering and drying require the most energy in the form of heat, while all other stages require electrical energy. The tea industry utilizes coal as a source of thermal energy to facilitate the withering and drying procedures of tea leaves⁹⁾. According to an energy audit, the production of 1kg of tea requires approximately 3.5-6 kWh of thermal energy and 0.21-0.5 kWh of electrical energy, with a thermal-to-electrical energy ratio of 85:15¹⁰⁾. By adding Zeolite-A, the withering time can be accelerated and drying time can also be accelerated¹¹⁾. Fossil fuels are commonly used for irrigation in tea plantations, contributing to the overall energy consumption. Tea manufacturing can potentially be shortened with the addition of Ethylene¹²⁾. Sources of low-temperature geothermal energy can also be used for the withering of tea leaves with the help of a heat pipe heat exchanger to improve the withering time¹³⁾. The percentage of energy consumed in different tea production processes, such as withering, processing, fermentation, drying, sifting, and packing are depicted in Fig 1.



**Pranjal Sarmah et al.,****Potential of Renewable Energy Sources for the Industry's Tea Plantations**

The traditional way of running the tea plantation through consuming fossil fuel contributes to global warming because greenhouse gases are released during such operations. It is imminent and necessary to switch to renewable sources of energy from the nonrenewable ones in order to eradicate the dangers of greenhouse gases, global warming and also the oil crisis associated with fossil fuels¹⁴. With the increase in cost of conventional fuels, industry is looking for alternative energy sources that do not rely on fossil fuel. However, renewable energy sources like solar wind hydro and biomass can supply power to tea plantations campuses or industries thereby reducing the harmful impacts of conventional fuel. By adopting energy-efficient technologies that are suitable for the available resources and meet the necessary requirements, the tea industry can significantly reduce production costs. A study conducted at Anandabag Tea Estate identified several such technologies that can be adopted based on their availability, suitability, and cost-effectiveness.

Possibilities of Hydro Power Plant in Anandabag Tea Estate

Hydro power plants produce electricity by turning its generators and turbines with the help of water that falls by the force of gravity. The advantage of hydro power plant is that it does not pollute the land, air, water etc. and produce electricity with minimal use of natural resources. The flowing water from mountains streams and clear lakes helps to produce hydroelectricity. Makum is located at Tinsukia district of Assam which is inhabitant of 16,923 people (as per 2011 census). The nearest water body to Anandabag Tea Estate is Tingrai which is at an approximate distance of 14km. To set a hydro power project there is a requirement of large reservoirs to store the water. The reservoir needs to be set up in agricultural fields which will cost the small-scale farmers to give up their farming lands, also it will bring a major threat to the nearby marine and aquatic life as water will be stored in a large scale. Storing of water at large scale may also result in small earthquakes to nearby inhabitant region. The micro hydroelectric power plant is appropriate for small industries situated in far-flung regions¹⁵. In the summertime, there is a significant reduction in the water movement rate of canals and streams, which may not be adequate to meet the energy demand during this season¹⁶. However, the solution to the hydro power project may be micro hydro power project which can produce output from 50kwh to 100 kwh. Micro hydro projects do not require reservoirs. From Table 6 it is clear that the micro hydro project will not be able to meet the power demand of the tea estate. Therefore, it will be beneficial to switch to other renewal sources like solar energy.(Data collected on 21/04/2022)

Possibilities of biomass in Anandabag Tea Estate

Biomass is a renewable and sustainable source of energy derived from organic matter such as plants, animals, and micro-organisms found on land and water, as well as their derivatives¹⁷. Tea plantations and industries produce three distinct types of biomass waste, including shade tree waste, garden waste, and tea waste. This waste can be converted into gaseous and liquid fuels such as methane, hydrogen, carbon monoxide, ethanol, and methanol, which can be used in engines. Biomass cogeneration is a process that produces both heat and electricity by utilizing a gas turbine to run a generator. The collection and conveyance of biomass require a significant amount of energy¹⁸. To produce energy for the withering and drying processes, a heat exchanger can be employed to generate hot air. There are three main processes used to convert biomass into energy or biofuels: direct combustion (burning), thermochemical conversion (pyrolysis and gasification), and biochemical conversion¹⁹. Burning is the most common method for biomass conversion, and it produces by-products called combustion products such as methanol, coal, and charcoal. Thermochemical conversion utilizes pyrolysis and gasification, while biochemical conversion involves using micro-organisms for conversion. Despite its many benefits, biomass conversion has certain drawbacks due to variations in raw material, moisture content, and other factors. For example, biomass production facilities require large spaces for storage and operation, and using wood to create biomass energy can lead to deforestation. Unclean combustion can also result in emissions, and biomass alone is not as efficient as fossil fuels. However, in the tea industry, biomass waste has significant potential for energy production. For instance, industrial tea waste has an estimated energy potential of -3.504×10^{10} kWh, and the thermal energy availability is estimated at 1.822×10^{10} kWh, which supplies 59% of the thermal energy requirement of the tea industry²⁰. Tea waste from the garden and industry was projected to have an energy potential of 1.86×10^{10} kWh and 4.47×10^7 kWh, respectively, in 2013. The tea industry's overall energy consumption was calculated to be 2.24×10^9 kWh, with biomass conversion to electrical



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energy being considered to have a 25% efficiency. These calculations suggest that biomass waste may supply 83% of the energy needed by the tea industry²¹. A large space is needed to grow the materials that are used in biomass energy. Amount of industrial and garden tea waste is about 2% of production of tea and 1.05 kg per bush respectively. In Anandabag the garden waste is decomposed and used as manure. The amount of waste collected can meet the manure requirement only. In this case, biomass project will not be worth the price, especially when solar, hydro power and wind alternatives are available⁵.

Possibilities of wind in Anandabag Tea Estate

Anandabag Tea Estate is in Makum region of Tinisukia District. It is at an elevation of 129.18 meters above sea level, Makum has a humid subtropical climate, with hot and humid summers and cool winters. The average temperature in summer (April to June) is around 30°C, while in winter (December to February) it can drop to as low as 10°C. Makum typically receives about 116.33 mm of rainfall and has 63.37 rainy days (17.36% of the time) annually. The uneven heating of the Earth's surface, which is caused by differences in solar radiation and thermal properties, does indeed result in the formation of wind. This uneven heating causes differences in air pressure, which in turn causes the air to move from high-pressure areas to low-pressure areas, resulting in the flow of air or wind. Wind turbines harness the kinetic energy of the wind and convert it into mechanical energy, which is then used to generate electricity. In comparison to solar plants, wind turbines have a shorter lifespan. However, the wind turbine's longevity can be enhanced through effective maintenance and implementation of appropriate strategies²². Turbulence, turbine dynamics, and controls are the chief mechanical hurdles associated with wind turbines²³. The expense of transporting the wind turbine to the location fundamentally impacts the economics of the wind turbine²⁴. However, the process of converting wind energy into electricity is a bit more complex than just using blades to rotate the rotor.

- The wind turbine blades are set to be able to capture the kinetic energy of the breeze, and when breezes blow through them, this start turning.
- The rotating blades are linked to a rotor that is coupled to the gearbox. The gearbox increases the speed of rotation to the rotor, enabling it to drive a generator.
- The generator makes electricity by converting mechanical energy from the spinning rotor to electrical power.
- The electrical grid then dispenses the electricity to homes, businesses, and other users.

Bottom of Form

A wind turbine's power output is exactly proportional to the wind speed cube. This implies that power production can rise significantly with a minor increase in wind speed. For instance, a 60% increase in power production from the same turbine can result from an increase in average wind speed from 6 m/s to 7 m/s. Additionally, this corresponds to a 36% rise in yearly energy production. Areas where wind speeds averaging 7 m/s or higher are typically seen to be suitable for installing wind turbines. With "oversized rotor" wind turbines, however, locations with typical wind speeds as low as 5.5 m/s can still be profitable. On the other hand, if the wind speed is less than 5 m/s, it is unlikely that a wind turbine installation would be economically viable²⁷. Wind turbines require:

- The minimum wind speed required for a wind turbine to begin turning and generate electricity is generally 12-14 km/hr.
- Wind of speed ranging from 50-60 km/hr. can generate at full capacity.
- To avoid damage, wind turbine should be stopped beyond of 90 km/hr. From the above tables it is clear that although Makum receives a good amount of wind speed but it not enough to meet the speed requirement to install a wind turbine. There is always a risk of accidental wind in Assam (as reported by The Economic Times on April 14, 2010: Assam recorded wind speed of 125 km/hr). This might result in overall damage of wind turbine and might have economic consequences for the tea estate.

Possibilities of Solar Power Plant in Anandabag Tea Estate

Solar energy is another form of fundamental source of renewable energy. Solar power for generation of electricity, solar thermal energy, solar architecture etc. are the technologies used commercially by utilizing solar energy²⁸. Solar



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energy is replacing fossil fuels because of its various benefits, as a source of power. Moreover, it does not release any greenhouse gases or other harmful by-product which is one of its major advantages²⁹. The wind turbine necessitates an upfront investment that accounts for 80% of the overall expenditure, whereas the solar PV power plant requires relatively lower initial spending³⁰. To reduce costs and maintain a reliable electricity supply many tea estates of Assam is now looking for various ways of renewable and environment friendly solar projects in Tea production³¹. Electricity is mainly used in tea production during irrigation, for operating machineries and this can be generated by solar photovoltaic systems. The solar thermal collectors can be used to generate the necessary thermal energy for the withering and drying processes³². Since India lies in the Northern Hemispherical equator region. Therefore the solar collector should be placed in the front of the structure in the south orientation³³⁻³⁵. In a solar thermal collector, solar radiation from the sun is first converted into heat and then transferred to a heat transfer fluid (HTF), which is used for withering and drying processes. Depending on the collector design, it may generate excess heat during periods of high solar insolation, which can be stored or utilized for other applications³⁶. On the other hand, in a solar photovoltaic (PV) system, solar radiation is directly converted into electricity by the PV panel. The energy generated is then regulated by a charger controller, stored in a battery, and converted into usable electricity by an inverter. This system can effectively replace the need for diesel pump sets in tea estates and significantly reduce reliance on fossil fuels⁵. However, a further challenge posed by solar photovoltaic (PV) technology is its incapability to provide an instantaneous response to changes in load demand. In other words, solar PV systems are unable to promptly adjust their power output to match the varying electricity needs of users³⁷. Moreover, its power generation remains suspended until any malfunctioning part is fixed or replaced³⁸. The monsoon season in Assam spans from June to October, followed by the winter season from November to February³⁹. During the period from March to June, there is a high demand for irrigation in the region. As a result, the tea industry primarily requires energy from March to November to meet its needs⁴⁰(fig4). In Anandabag Tea estate, installation of solar panel would be effective by reducing the energy consumption or various power costs during the production. As that amount of sunlight is enough to install solar panels, so during the period of maximum production solar energy can be used as an alternative of non-renewable energy.

CONCLUSIONS

In this project we have studied the tea machinery process, energy requirement in Anandabag Tea Estate and the possible source of renewal energy that can replace the conventional source of energy that are being used in Anandabag Tea Estate. From which we have found out that- There is a possibility for biomass energy but it will not be able to meet the energy requirement of the industry. Constructing large hydro power project will not be possible as the Tea Estate is far away from its nearest water body. Construction micro hydro power project will not be able to meet the energy requirement of the industry. The average wind speed of Makum is less than 5 m/s which is below the minimum wind speed required to produce energy economically. Solar energy could be used to meet the electricity needs of tea gardens and industries. Thus, in order to remain competitive in the global tea market, Anandabag Tea Estate needs to adopt sustainable practices for tea production by replacing conventional methods with renewable energy sources. This will not only enhance productivity and market value, but also address environmental and social concerns. By utilizing renewable energy sources, the tea estate can improve its sustainability and maintain its position in the global tea market.

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Table 1. Manufacture Reports

Date	Own Leaf (Kgs)	Bought Leaf (Kgs)	Total Green Leaf (Kgs) , G	Wither Leaf (Kgs)	Trough Withering Percentage
21/4/22	4393	2970	7263	5120	69.54
31/4/22	16783	10595	37992	26710	70.30





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Table 2. APDCL

Month	Tea Made	Apdcl Unit	Bill Amount	Unit/Kg	Unit Cost	Cost/Kg
January	Nil	7873	82453.00	-	10.47	-
February	305	7370	76,516.00	24.16	10.38	250.87
March	33,925	20146.5	200,282.00	0.59	9.94	5.90
April	52760	35,241	312,344.00	0.67	8.86	5.92
May	55745	26,730	245,324.00	0.48	9.17	4.40
June	59085	36,085.5	373,389.00	0.61	10.35	6.32

Table 3. GAS

Months	Tea Made	Total Gas Scum	Bill Amount	Scum/Kg	Scum Cost	Cost/Kg
January	Nil					
February	305					
March	33925	57187.6	340,241.00	1.67	5.95	9.94
April	52,760	93,890.7	14,11,825.00	1.78	15.03	26.76
May	55,745	90,606.0	1294153.00	1.68	14.28	23.21
June	59,085	75,815.0	1033,719	1.28	13.63	17.50

Table 4. Month wise Cost Statement for the year 2022

Month	Tea Made	HSD Used	Unit Generator	Unit Per Ltr	HSD Cost	Unit Cost	Unit Per Kg	Cost Per Kg
January	-							
February	305	-						
March	33,925	1826	5131.06	2.81	158,295.94	30.85	0.15	4.67
April	52,760	2756	7744.36	2.81	252091.32	32.55	0.15	4.78
May	55,745	3760	10,565.60	2.81	315,840.00	29.89	0.18	5.67
June	59,085	3484	9790.04	2.81	292,656.00	29.89	0.16	4.95

Table 5. Power consumption

Power Source	APDCL	Natural Gas	HSD
Unit (in kwh)	1355.42	198.88	297.86

Table 6. Wind Speed of Makum²⁵⁾

Date (April 2020)	Wind Speed (kmph)	Date (April 2020)	Wind Speed (kmph)	Date (April 2020)	Wind Speed (kmph)
1	4	11	5	21	6
2	8	12	6	22	9
3	6	13	4	23	8
4	7	14	5	24	6
5	6	15	5	25	5
6	5	16	8	26	4
7	5	17	6	27	4
8	5	18	5	28	5
9	8	19	6	29	6
10	7	20	7	30	5





Table 7. Wind speed month wise in Makum 2020

Month (2020)	Wind Speed (kmph)			Gust	Wind In kmph	
	Max	Min	Avg		Max	Min
January	6	2	3.9	9	3	5.87
February	7	3	4	10	4	6.14
March	7	3	4.26	12	4	6.14
April	9	4	5.87	13	6	5.27
May	8	3	4.81	13	5	7.58
June	8	3	5.03	15	4	8.23
July	8	4	5.48	13	5	8.84
August	8	2	4.71	13	4	8.03
September	8	1	4.7	14	2	7.8
October	7	2	3.19	11	3	5.39
November	5	2	2.9	8	3	4.53
December	3	2	2.71	5	3	4.42

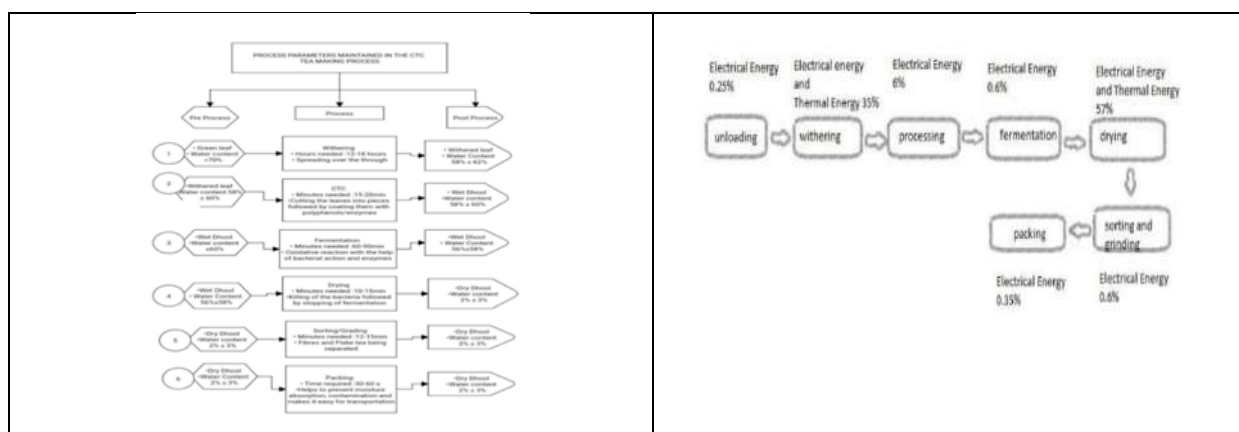


Fig:1

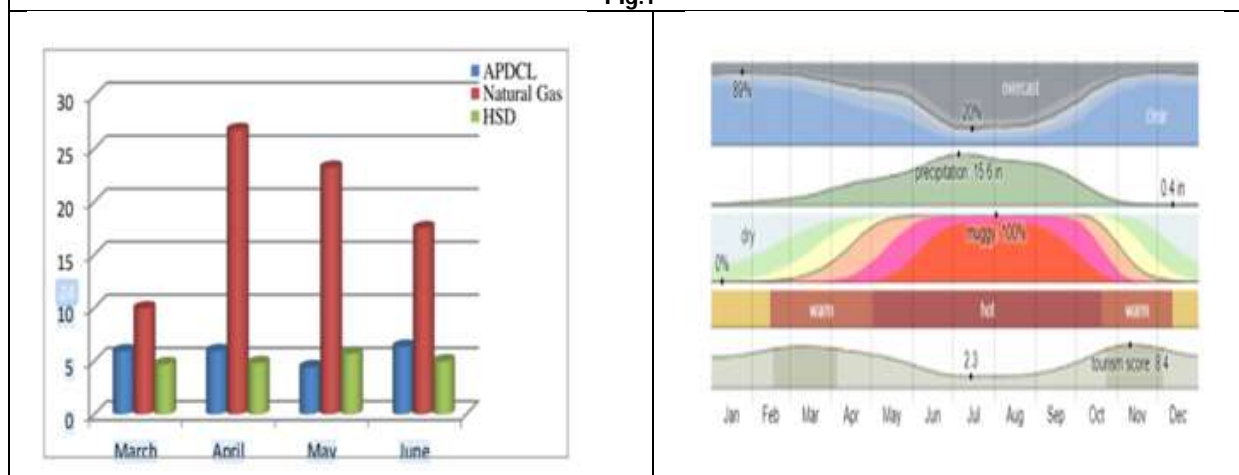


Fig.2: Cost per kg analysis

Fig 3: Climate in Tinsukia41)





Selecting Nutrition and Diet for Toddlers with Iron Deficiency using a Neutrosophic Hypersoft Matrix

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ABSTRACT

Present study provides a comparison of extended techniques based on the score function algorithm in a neutrosophic hyper-soft environment. The solution approaches are utilized to solve a mathematical modeling problem of determining the most important nutrition and diet for toddlers with iron deficiency. Our current methodology is compared to the different MCDM (multi-criteria decision-making) methodologies. In addition, a practical instance is offered to show how effective our newly improved techniques are.

Keywords: NHSs (Neutrosophic Hypersoft sets), NHSM (Neutrosophic Hypersoft matrix), Basic results of NHSM, Decision Making, Score function.

INTRODUCTION

Nutrition and diet are crucial in helping toddlers with iron deficiency. For optimal energy levels, cognitive development, and immune system function, adequate iron intake is necessary. An iron-rich, well-balanced diet aids in the prevention of anemia, encourages healthy growth, and enhances emotional well-being. It is possible for caregivers to significantly improve their toddlers' overall health and instill healthy eating habits that will last a lifetime. In 1998, F. Smarandache[1] introduced the idea of Ns (Neutrosophic set), which is a generalization of Ifs





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(Intuitionistic fuzzy set) and Fs (Fuzzy set). The main mathematical tool for handling difficulties with decision-making in ambiguous environments is the Ss (Soft set) theory, which was created by Molodtsov [2] in 1999. P. K. Maji [3] categorized a wide variety of operators for NSs (Neutrosophic Soft set) in unexpected problems. In 2015, Deli, Irfan and Broumi [4] developed NSMs (Neutrosophic Soft matrices) and applied SMs (Soft matrices) to make decisions. Jafar, Muhammad Naveed, et al. [5] proposed a new agriculture technology utilizing NSMs and the scoring function. In 2023, R. Sophia Porchelvi and P. Subashini [6] proposed the NSM concept to deal with maternal diet issues. HSS is a continuation of Ss theory, it was presented by F. Smarandache [7] in 2018, to create multiple characteristics in an uncertainty-handling function. R. M. Zulqarnaian et al. [8] created the new concept of NHSSs with appropriate operations and attributes by combining the HSS and NHSSs concepts. To simplify the NHSSs framework, in 2021, R. M. Zulqarnaian et al. [9] provide the idea of NHSM as well as certain basic operators and procedures. Following that, in 2024, J. Jayasudha and S. Raghavi [10] proposed certain NHSM procedures to handle medical diagnostic problems using a choice matrix. Neutrosophic soft matrices parametrically evaluate the specified characteristics, whereas Neutrosophic soft matrices allow for parametric evaluation of the sub-attributes of the chosen attributes. The current study aims to apply new decision-making techniques to NHSSs and the MCDM problem. We structure our manuscript as follows: Section 2 reviews the fundamental explanations of NHSSs. In parts 3 and 4, we use the new score function methodology to solve the most essential nutrition and diet problem for toddlers with iron deficiency. Section 5 compares our proposed methodology to existing methodologies, and Section 6 presents the result.

PRELIMINARIES

Definition 2.1: [9]

Let \mathcal{p} represent a universal set and $\mathbb{P}(\mathcal{p})$ represent its powerset. Let $f^1, f^2, f^3, \dots, f^n$ for $n \geq 1$, be well defined characteristics (attributes), these corresponding characteristics (attribute) values are the set $\hat{F}^1, \hat{F}^2, \hat{F}^3, \dots, \hat{F}^n$ with $\hat{F}^i \cap \hat{F}^j = \emptyset$, for $i \neq j$ and $i, j \in \{1, 2, 3, \dots, n\}$. A pair $(\mathbb{E}, \hat{F}^1 \times \hat{F}^2 \times \hat{F}^3 \dots \hat{F}^n)$ is referred to as a **Hyper soft set** (HSS) over \mathcal{p} , where

$$\mathbb{E}: \hat{F}^1 \times \hat{F}^2 \times \hat{F}^3 \dots \hat{F}^n \rightarrow \mathbb{P}(\mathcal{p}).$$

Definition 2.2: [9]

Let \mathcal{p} represent a universal set and $\mathbb{P}(\mathcal{p})$ represent its powerset. Let $f^1, f^2, f^3, \dots, f^n$ for $n \geq 1$, be well defined characteristics (attributes). The set of related characteristic (attribute) values $\hat{F}^1, \hat{F}^2, \hat{F}^3, \dots, \hat{F}^n$ with $\hat{F}^i \cap \hat{F}^j = \emptyset$, for $i \neq j$ and $i, j \in \{1, 2, 3, \dots, n\}$, and let $\hat{F}^1 \times \hat{F}^2 \times \hat{F}^3 \dots \hat{F}^n = S$. The pair (\mathbb{E}, S) is referred to as a **Neutrosophic Hyper soft set** (NHSS) over \mathcal{p} , where $\mathbb{E}: \hat{F}^1 \times \hat{F}^2 \times \hat{F}^3 \dots \hat{F}^n \rightarrow \mathbb{P}(\mathcal{p})$ and $(\mathbb{E}, \hat{F}^1 \times \hat{F}^2 \times \hat{F}^3 \dots \hat{F}^n) = \{ \langle x, T(S), I(S), F(S) \rangle, x \in \mathcal{p} \}$ where T, I , and F represent the truth, indeterminacy, and falsity grade values such that $T, I, F: \mathcal{p} \rightarrow [0, 1]$ also $0 \leq T(S) + I(S) + F(S) \leq 3$.

Definition 2.3: [9]

Let $\mathcal{p} = \{v^1, v^2, v^3, \dots, v^\sigma\}$ represent a universal set, and $\mathbb{P}(\mathcal{p})$ represent its power set. Let $\mathbb{Y}_1, \mathbb{Y}_2, \dots, \mathbb{Y}_\delta$ for $\delta \geq 1$, δ well defined characteristics. The set of related characteristic values $\mathbb{Y}_1^{a_i}, \mathbb{Y}_2^{b_i}, \dots, \mathbb{Y}_\delta^{z_i}$ and their relation $\mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i}$ where $a_i, b_i, c_i, \dots, z_i = 1, 2, 3, \dots, \delta$. A pair $(\mathbb{E}, \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i})$ is called NHSSs over \mathcal{p} , where $\mathbb{E}: \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i} \rightarrow \mathbb{P}(\mathcal{p})$, and it is characterized as, $\mathbb{E}(\mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i}) = \{v, T_r(v), I_r(v), F_r(v): v \in \mathcal{p}, r \in \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i}\}$. The relation $Z_r = \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i}$ has the following characteristic function: $X_{Z_r} = \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i} \rightarrow \mathbb{P}(\mathcal{p})$; It's defined as $X_{Z_r} = \{v, T_r(v), I_r(v), F_r(v): v \in \mathcal{p}, r \in \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots, \mathbb{Y}_\delta^{z_i}\}$ and can be a representation of Z_r as given in Table 1. If $J_{rs} = X_{Z_r}(v^r, \mathbb{Y}_s^t)$, where $r = 1, 2, \dots, \sigma, s = 1, 2, \dots, \delta, t = a_i, b_i, c_i, \dots, z_i$, then the matrix can be represented as follows:

$$[J_{rs}]_{\sigma \times \delta} = \begin{pmatrix} J_{11} & J_{12} & \dots & J_{1\delta} \\ J_{21} & J_{22} & \dots & J_{2\delta} \\ \vdots & \vdots & \ddots & \vdots \\ J_{\sigma 1} & J_{\sigma 2} & \dots & J_{\sigma \delta} \end{pmatrix}$$





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Where,

$$J_{rs} = (T_{\mathbb{Y}_r^t}(v_r), I_{\mathbb{Y}_r^t}(v_r), F_{\mathbb{Y}_r^t}(v_r)) : v_r \in V, \mathbb{Y}_r^t \in \mathbb{Y}_1^{a_i} \times \mathbb{Y}_2^{b_i} \times \dots \times \mathbb{Y}_\delta^{d_i} = (T_{rst}^L, I_{rst}^L, F_{rst}^L)$$

As a result, we may use the NHSM to represent any NHSS, showing that both are transferable.

Definition 2.4: [10]

Let $\mathbb{Q} = [(T_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{Q}})] \in NHSM_{\sigma \times \delta}$. The **complement matrix** of \mathbb{Q} is represented by \mathbb{Q}° & can be stated as $\mathbb{Q}^\circ = [F_{ij}^{\mathbb{Q}}, 1 - I_{ij}^{\mathbb{Q}}, T_{ij}^{\mathbb{Q}}] \forall i, j$.

Definition 2.5: [9]

Let $\mathbb{Q} = [(T_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{Q}})] \in NHSM_{\sigma \times \delta}$, $\mathbb{H} = [(T_{ij}^{\mathbb{H}}, I_{ij}^{\mathbb{H}}, F_{ij}^{\mathbb{H}})] \in NHSM_{\sigma \times \delta}$. Then, the two **OR-Operations** \mathbb{Q} and \mathbb{H} are stated as: $T(\mathbb{Q} \vee \mathbb{H}) = \max \{T_{ij}^{\mathbb{Q}}, T_{ij}^{\mathbb{H}}\}$, $I(\mathbb{Q} \vee \mathbb{H}) = \min \{I_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{H}}\}$, $F(\mathbb{Q} \vee \mathbb{H}) = \min \{F_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{H}}\}$.

Definition 2.6: [9]

Let $\mathbb{Q} = [(T_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{Q}})] \in NHSM_{\sigma \times \delta}$, $\mathbb{H} = [(T_{ij}^{\mathbb{H}}, I_{ij}^{\mathbb{H}}, F_{ij}^{\mathbb{H}})] \in NHSM_{\sigma \times \delta}$. Then, the two **AND-Operations** \mathbb{Q} and \mathbb{H} are stated as: $T(\mathbb{Q} \wedge \mathbb{H}) = \min \{T_{ij}^{\mathbb{Q}}, T_{ij}^{\mathbb{H}}\}$, $I(\mathbb{Q} \wedge \mathbb{H}) = \max \{I_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{H}}\}$, $F(\mathbb{Q} \wedge \mathbb{H}) = \max \{F_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{H}}\}$.

Definition 2.7: [5]

Let $\mathbb{Q} = [(T_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{Q}})] \in NHSM_{\sigma \times \delta}$. $V(\mathbb{Q})$ represents the **value matrix** of \mathbb{Q} is stated as $V(\mathbb{Q}) = [(T_{ij}^{\mathbb{Q}} + I_{ij}^{\mathbb{Q}} - F_{ij}^{\mathbb{Q}})] \forall i, j$ respectively.

Definition 2.8: [5]

Let $\mathbb{Q} = [(T_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{Q}})] \in NHSM_{\sigma \times \delta}$, $\mathbb{H} = [(T_{ij}^{\mathbb{H}}, I_{ij}^{\mathbb{H}}, F_{ij}^{\mathbb{H}})] \in NHSM_{\sigma \times \delta}$. The equation $S_{(\mathbb{Q}, \mathbb{H})} = V(\mathbb{Q}) - V(\mathbb{H})$ defines the **score** for these two NHSMs, it is expressed as $S_{(\mathbb{Q}, \mathbb{H})}$.

Definition 2.9: [5]

Let $\mathbb{Q} = [(T_{ij}^{\mathbb{Q}}, I_{ij}^{\mathbb{Q}}, F_{ij}^{\mathbb{Q}})] \in NHSM_{\sigma \times \delta}$, $\mathbb{H} = [(T_{ij}^{\mathbb{H}}, I_{ij}^{\mathbb{H}}, F_{ij}^{\mathbb{H}})] \in NHSM_{\sigma \times \delta}$. Then their respective value matrix be $V(\mathbb{Q})$, $V(\mathbb{H})$ and their scoring matrix is represented by $S_{(\mathbb{Q}, \mathbb{H})}$. The overall score (**total score**) of every v_i in \mathcal{P} is calculated as follows:

$$S_i = \sum_{j=1}^n |V(\mathbb{Q}) - V(\mathbb{H})|$$

A score-based decision-making methods for Neutrosophic Hyper soft Matrices

This section, we describe a MCDM method that uses a value matrix and a score matrix to solve the problem. Consider the decision-making issues presented by Jafar, Muhammad Naveed, et al. [5].

Algorithm

Step: 1 Calculate the neutrosophicity per soft sets (E_1, \mathbb{Q}) , (E_2, \mathbb{H}) and there after determine the associated NHSMs \mathbb{Q} and \mathbb{H} for (E_1, \mathbb{Q}) , (E_2, \mathbb{H}) accordingly.

Step: 2 Calculate the neutrosophicity per soft complement sets (E_1, \mathbb{Q}) and (E_2, \mathbb{H}) , as well as the NHSMs \mathbb{Q}° and \mathbb{H}° that correspond to (E_1, \mathbb{Q}) and (E_2, \mathbb{H}) .

Step: 3 Obtain the value matrices for NHSMs and neutrosophicity per soft complement matrices using the OR-operation, which are denoted by $V[M_{(\mathbb{Q} \vee \mathbb{H})}]$ and $V[M_{(\mathbb{Q}^\circ \vee \mathbb{H}^\circ)}]$.

Step: 4 Calculate the score matrix $S_{(\mathbb{Q} \vee \mathbb{H}, \mathbb{Q}^\circ \vee \mathbb{H}^\circ)}$ from the value matrices.

Step: 5 Compute the (overall score) total score value S_i for every object in \mathcal{P} . The highest score is the optimum solution.





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Algorithm-2

Step: 1 Construct the neutrosophichypersoft sets (E_1, \mathbb{Q}) , (E_2, \mathbb{H}) and thereafter determine the associated NHSMs \mathbb{Q} and \mathbb{H} for (E_1, \mathbb{Q}) , (E_2, \mathbb{H}) accordingly.

Step: 2 Calculate the neutrosophichypersoft complement sets (E_1, \mathbb{Q}) and (E_2, \mathbb{H}) , as well as the NHSMs \mathbb{Q}° and \mathbb{H}° that correspond to (E_1, \mathbb{Q}) and (E_2, \mathbb{H}) .

Step: 3 Calculate the value matrices for NHSMs and neutrosophichypersoft complement matrices using the AND-operation, which are denoted by $V[M_{(\mathbb{Q} \vee \mathbb{H})}]$ and $V[M_{(\mathbb{Q}^\circ \vee \mathbb{H}^\circ)}]$.

Step: 4 Calculate the score matrix $S_{(\mathbb{Q} \vee \mathbb{H}, \mathbb{Q}^\circ \vee \mathbb{H}^\circ)}$ from the value matrices.

Step: 5 Compute the (overall score) total score values S_i for every object in \mathcal{P} . The highest score is the optimum solution.

Case Study

Nutrition is crucial to the rapid growth and development of toddlers. At this point, a diet that should include variety of foods to ensure that the vitamins and minerals your child needs are obtained. The current study seeks to discover the most nutrient-dense diet for toddlers with iron deficiency. The most suitable alternative was chosen by the researcher after consulting with two medical professionals and making use of their information. Iron is a mineral with numerous applications. Iron improves a child's ability to learn and assists (RBC) red blood cells in transporting oxygen throughout the body. Anemia and iron deficiency can be prevented with adequate iron intake. The following is a list of foods high in iron that are great for toddlers:

- **Fruits:** Oranges, kiwi, raisins, figs, strawberries, prunes, dates
- **Vegetables:** Sweet potatoes, peas, string beans, broccoli.
- **Heme Iron from Animal Sources:** Eggs, Beef, Pork, Lamb, Ham, Turkey, Chicken, Liver, Liverwurst, Salmon fish, Tuna fish, Prawns, Mackerel fish.
- **Iron from plants other than Heme(Non-Heme Iron):** Pulses (mixed beans, chickpeas and lentils, baked beans), leafy vegetables (Kale, Spinach, Swiss chard), nuts & seeds (Almonds in small safe amounts, sunflower seed, pumpkin seed) and Dried fruits.
- **Fortified Foods:** Breakfast cereals, Bread, yogurt, milk, soy milk and other milk alternatives. The recommended dietary intake (RDI) of iron for toddlers varies based on their age and gender. In table 2, we provide the required quantity of iron per day based on age group.

Numerical Example

A parent has sought the advice of two medical professionals about the optimal nutrition and diet for toddlers with iron deficiency. The professionals offer the following specific nutrients and dietary options to address the needs of this condition.

$N = \{\text{Fruits } (Nu_1), \text{Vegetables } (Nu_2), \text{Heme Iron } (Nu_3), \text{Non-Heme Iron } (Nu_4), \text{Fortified Food } (Nu_5)\}$

A parent wants to know about the most essential nutrition and diet for their toddler's. To provide correct advice, the professional must examine the toddler's iron levels. Based on this assessment, the specialist will make recommendations for dietary alternatives that best support the toddler's nutritional needs. They are as follows:

$E = \{\mathbb{Y}_1 = \text{Age}, \mathbb{Y}_2 = \text{Gender}, \mathbb{Y}_3 = \text{Hemoglobin level}, \mathbb{Y}_4 = \text{Ferritin level (in blood serum)}\}$.

Furthermore, the previously mentioned characteristics have evolved into various categories, which can be classed as follows:

$\mathbb{Y}_1^a = \text{Age} = \{1\text{-}2 \text{ years}, 2\text{-}3 \text{ years}\}$, $\mathbb{Y}_2^b = \text{Gender} = \{\text{Boy}, \text{Girl}\}$,

$\mathbb{Y}_3^c = \text{Hb level} = \{< 8 \text{ g/dL}, 8\text{-}9 \text{ g/dL}, 9\text{-}10 \text{ g/dL}, 10\text{-}11.4 \text{ g/dL}\}$,

$\mathbb{Y}_4^d = \text{Ferritin level (in blood serum)} = \{< 5 \text{ ng/mL}, 5\text{-}6.2 \text{ ng/mL}, 6.2\text{-}6.8 \text{ ng/dL}\}$.

Neutrosophichypersoft set is defined as, $\mathbb{E}: \mathbb{Y}_1^a \times \mathbb{Y}_2^b \times \mathbb{Y}_3^c \times \mathbb{Y}_4^d \rightarrow \mathbb{P}(\mathcal{P})$. Assuming the relation $\mathbb{E}(\mathbb{Y}_1^a \times \mathbb{Y}_2^b \times \mathbb{Y}_3^c \times \mathbb{Y}_4^d)$ corresponds to the toddler's details, we have: $\mathbb{E}(2\text{-}3 \text{ years}, \text{Girl}, 8\text{-}9 \text{ g/dL}, 5\text{-}6.2 \text{ ng/mL})$, this represents particular information about the toddler's age, gender, hemoglobin level, and ferritin status. On this basis, four nutrition and diet are shortlisted Nu_1, Nu_2, Nu_3, Nu_4 according to the above - mentioned relation (2-3 years, Girl, 8-9 g/dL, 5-6.2 ng/mL).





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Two medical professionals consign their opinions on each possibility as part of an NHSS as stated below:

$\mathbb{E}(P_1, \mathbb{Q}) = \mathbb{E}(2-3 \text{ years, Girl, } 8-9 \text{ g/dL, } 5-6.2 \text{ ng/mL})$

$$= \begin{pmatrix} (Nu_1, \{0.5, 0.3, 0.1\}, \{0.6, 0.2, 0.1\}, \{0.7, 0.3, 0.1\}, \{0.5, 0.5, 0.2\}) \\ (Nu_2, \{0.6, 0.5, 0.1\}, \{0.5, 0.3, 0.8\}, \{0.9, 0.1, 0.8\}, \{0.7, 0.8, 0.2\}) \\ (Nu_3, \{0.3, 0.4, 0.5\}, \{0.2, 0.3, 0.1\}, \{0.1, 0.5, 0.4\}, \{0.2, 0.6, 0.7\}) \\ (Nu_4, \{0.7, 0.8, 0.1\}, \{0.5, 0.6, 0.2\}, \{0.3, 0.1, 0.1\}, \{0.7, 0.8, 0.2\}) \end{pmatrix}$$

$\mathbb{E}(P_2, \mathbb{H}) = \mathbb{E}(2-3 \text{ years, Girl, } 8-9 \text{ g/dL, } 5-6.2 \text{ ng/mL})$

$$= \begin{pmatrix} (Nu_1, \{0.2, 0.3, 0.4\}, \{0.5, 0.6, 0.1\}, \{0.8, 0.2, 0.7\}, \{0.3, 0.1, 0.1\}) \\ (Nu_2, \{0.3, 0.5, 0.5\}, \{0.6, 0.7, 0.1\}, \{0.2, 0.8, 0.3\}, \{0.9, 0.1, 0.3\}) \\ (Nu_3, \{0.8, 0.8, 0.1\}, \{0.9, 0.5, 0.2\}, \{0.3, 0.5, 0.5\}, \{0.6, 0.6, 0.7\}) \\ (Nu_4, \{0.8, 0.9, 0.7\}, \{0.3, 0.2, 0.1\}, \{0.2, 0.2, 0.1\}, \{0.7, 0.3, 0.1\}) \end{pmatrix}$$

Use the algorithm developed above, as indicated below:

Algorithm-1

Step:1 The two previously mentioned NHSSs can be represented as NHSMs as follows:

$$(\mathbb{E}_1, \mathbb{Q}) = \begin{bmatrix} (0.5, 0.3, 0.1) & (0.6, 0.2, 0.1) & (0.7, 0.3, 0.1) & (0.5, 0.5, 0.2) \\ (0.6, 0.5, 0.1) & (0.5, 0.3, 0.8) & (0.9, 0.1, 0.8) & (0.7, 0.8, 0.2) \\ (0.3, 0.4, 0.5) & (0.2, 0.3, 0.1) & (0.1, 0.5, 0.4) & (0.2, 0.6, 0.7) \\ (0.7, 0.8, 0.1) & (0.5, 0.6, 0.2) & (0.3, 0.1, 0.1) & (0.7, 0.8, 0.2) \end{bmatrix}$$

$$(\mathbb{E}_2, \mathbb{H}) = \begin{bmatrix} (0.2, 0.3, 0.4) & (0.5, 0.6, 0.1) & (0.8, 0.2, 0.7) & (0.3, 0.1, 0.1) \\ (0.3, 0.5, 0.5) & (0.6, 0.7, 0.1) & (0.2, 0.8, 0.3) & (0.9, 0.1, 0.3) \\ (0.8, 0.8, 0.1) & (0.9, 0.5, 0.2) & (0.3, 0.5, 0.5) & (0.6, 0.6, 0.7) \\ (0.8, 0.9, 0.7) & (0.3, 0.2, 0.1) & (0.2, 0.2, 0.1) & (0.7, 0.3, 0.1) \end{bmatrix}$$

Step:2 Calculate the complement matrix $(\mathbb{E}_1, \mathbb{Q})^\circ, (\mathbb{E}_2, \mathbb{H})^\circ$ of the above neutrosophic hypersoft matrices,

$$(\mathbb{E}_1, \mathbb{Q})^\circ = \begin{bmatrix} (0.1, 0.7, 0.5) & (0.1, 0.8, 0.6) & (0.1, 0.7, 0.3) & (0.2, 0.5, 0.5) \\ (0.1, 0.5, 0.6) & (0.8, 0.7, 0.5) & (0.8, 0.9, 0.9) & (0.2, 0.2, 0.7) \\ (0.5, 0.6, 0.3) & (0.1, 0.7, 0.2) & (0.4, 0.5, 0.1) & (0.7, 0.4, 0.8) \\ (0.1, 0.2, 0.7) & (0.2, 0.4, 0.5) & (0.1, 0.9, 0.3) & (0.2, 0.2, 0.7) \end{bmatrix}$$

$$(\mathbb{E}_2, \mathbb{H})^\circ = \begin{bmatrix} (0.4, 0.7, 0.2) & (0.1, 0.4, 0.5) & (0.7, 0.8, 0.8) & (0.1, 0.9, 0.3) \\ (0.5, 0.5, 0.3) & (0.1, 0.3, 0.6) & (0.3, 0.2, 0.2) & (0.3, 0.9, 0.9) \\ (0.1, 0.2, 0.8) & (0.2, 0.5, 0.9) & (0.5, 0.5, 0.3) & (0.7, 0.4, 0.6) \\ (0.7, 0.1, 0.8) & (0.2, 0.8, 0.3) & (0.1, 0.8, 0.2) & (0.1, 0.7, 0.7) \end{bmatrix}$$

Step:3 To compute value matrices for NHSMs using definitions 2.7 and 2.9.

$$M_{(\mathbb{Q} \vee \mathbb{H})} = (\mathbb{E}_1, \mathbb{Q}) \vee (\mathbb{E}_2, \mathbb{H}) = \begin{bmatrix} (0.5, 0.3, 0.1) & (0.6, 0.2, 0.1) & (0.8, 0.2, 0.1) & (0.5, 0.1, 0.1) \\ (0.6, 0.5, 0.1) & (0.6, 0.3, 0.1) & (0.9, 0.1, 0.3) & (0.9, 0.1, 0.2) \\ (0.8, 0.4, 0.1) & (0.9, 0.3, 0.1) & (0.3, 0.5, 0.4) & (0.6, 0.6, 0.7) \\ (0.8, 0.8, 0.1) & (0.3, 0.2, 0.1) & (0.3, 0.1, 0.1) & (0.7, 0.3, 0.1) \end{bmatrix}$$





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$$M_{(Q \vee H^*)} = (E_1, Q) \circ (E_2, H) = \begin{bmatrix} (0.4,0.7,0.2) & (0.1,0.4,0.5) & (0.7,0.7,0.3) & (0.1,0.5,0.3) \\ (0.5,0.5,0.3) & (0.8,0.3,0.5) & (0.8,0.2,0.2) & (0.3,0.2,0.7) \\ (0.5,0.2,0.3) & (0.2,0.5,0.2) & (0.5,0.5,0.1) & (0.7,0.4,0.6) \\ (0.7,0.1,0.7) & (0.2,0.4,0.3) & (0.1,0.8,0.2) & (0.2,0.2,0.7) \end{bmatrix}$$

$$V[M_{(Q \vee H)}] = \begin{bmatrix} 0.7 & 0.7 & 0.9 & 0.5 \\ 1 & 0.8 & 0.7 & 0.8 \\ 1.1 & 1.1 & 0.4 & 0.5 \\ 1.5 & 0.4 & 0.3 & 0.9 \end{bmatrix}$$

$$V[M_{(Q^* \vee H^*)}] = \begin{bmatrix} 0.9 & 0 & 1.1 & 0.3 \\ 0.7 & 0.6 & 0.8 & -0.2 \\ 0.4 & 0.5 & 0.9 & 0.5 \\ 0.1 & 0.3 & 0.7 & -0.3 \end{bmatrix}$$

Step: 4 Subtract $V[M_{(Q \vee H)}]$ and $V[M_{(Q^* \vee H^*)}]$ to get the score matrix.

$$S_{(Q \vee H, Q^* \vee H^*)} = \begin{bmatrix} -0.2 & 0.7 & -0.2 & 0.2 \\ 0.3 & 0.2 & -0.1 & 1 \\ 0.7 & 0.6 & -0.5 & 0 \\ 1.4 & 0.1 & -0.4 & 1.2 \end{bmatrix}$$

Step:5 The total score can be calculated using the above score matrix values as follows:

$$\text{Total score} = \begin{bmatrix} 0.5 \\ 1.4 \\ 0.8 \\ 2.3 \end{bmatrix}$$

According to the above total score value, the four alternatives are ranked as follows:

$$Nu_4 > Nu_2 > Nu_3 > Nu_1.$$

Algorithm – 2

The first two steps are identical to those cited in Algorithm 1; hence we elaborate on the remaining phases as follows:

Step:3 To calculate value matrices of NHSMs using the definitions 2.8 and 2.9.

$$M_{(Q \wedge H)} = (E_1, Q) \wedge (E_2, H) = \begin{bmatrix} (0.2,0.3,0.4) & (0.5,0.6,0.1) & (0.7,0.3,0.7) & (0.3,0.5,0.2) \\ (0.3,0.5,0.5) & (0.5,0.7,0.8) & (0.2,0.8,0.8) & (0.7,0.8,0.3) \\ (0.3,0.8,0.5) & (0.9,0.3,0.1) & (0.3,0.5,0.5) & (0.2,0.6,0.7) \\ (0.7,0.9,0.7) & (0.3,0.6,0.2) & (0.2,0.2,0.1) & (0.7,0.8,0.2) \end{bmatrix}$$

$$M_{(Q^* \wedge H^*)} = (E_1, Q) \circ (E_2, H) = \begin{bmatrix} (0.1,0.7,0.5) & (0.1,0.8,0.6) & (0.1,0.8,0.8) & (0.1,0.9,0.5) \\ (0.1,0.5,0.6) & (0.1,0.7,0.6) & (0.3,0.9,0.9) & (0.2,0.9,0.9) \\ (0.1,0.6,0.8) & (0.1,0.7,0.9) & (0.4,0.5,0.1) & (0.7,0.4,0.8) \\ (0.1,0.2,0.8) & (0.2,0.8,0.5) & (0.1,0.9,0.3) & (0.1,0.7,0.7) \end{bmatrix}$$

$$V[M_{(Q \wedge H)}] = \begin{bmatrix} 0.1 & 1 & 0.3 & 0.6 \\ 0.3 & 0.4 & 0.2 & 1.2 \\ 0.6 & 1.1 & 0.3 & 0.1 \\ 0.9 & 0.7 & 0.3 & 1.3 \end{bmatrix}$$

$$V[M_{(Q^* \wedge H^*)}] = \begin{bmatrix} 0.3 & 0.3 & 0.1 & 0.5 \\ 0 & 0.2 & 0.3 & 0.2 \\ -0.1 & -0.1 & 0.8 & 0.3 \\ -0.5 & 0.5 & 0.7 & 0.1 \end{bmatrix}$$





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Step:4 Determine the score matrix in accordance with definition 2.10.

$$S_{(Q \wedge A, Q^{\circ} \wedge A^{\circ})} = \begin{bmatrix} -0.2 & 0.7 & 0.2 & 0.1 \\ 0.3 & 0.2 & -0.1 & 1 \\ 0.5 & 1 & -0.5 & -0.2 \\ 1.4 & 0.2 & -0.4 & 1.2 \end{bmatrix}$$

Step: 5 The total score can be determined using the above score matrix data in the following manner:

$$\text{Total score} = \begin{bmatrix} 0.8 \\ 1.4 \\ 0.8 \\ 2.4 \end{bmatrix}$$

The four alternatives are ordered in the following order based on the total score value:

$$Nu_4 > Nu_2 > Nu_3 > Nu_1.$$

Among the alternatives, Nu_4 holds the largest value, indicating that it's the most preferred option.

RESULTS AND DISCUSSION

Non-heme iron (Nu_4) is essential for toddlers with iron insufficiency, according to the above outcomes. While all iron-rich foods have nutritional benefits, those high in non-heme iron are especially advantageous in deficiency conditions. The same result is reached by applying algorithms 1 and 2. Table 3 provides a comparison of the suggested methods to existing methodologies.

CONCLUSION

Neutrosophic hyper-soft matrices are especially useful in complex decision-making settings, improving evaluation accuracy and efficacy. Using a score matrix, new extended decision-making techniques were developed in this paper to resolve the MCDM problem. As a result of the obtained outcomes, it is possible to conclude with confidence the suggested approach provides a solution to the nutrition and diet issue. In order to guarantee that the established strategy can be implemented, a comparison analysis has been conducted. The neutrosophic framework's analytical capabilities are enhanced by the hyper-soft matrix, making it a useful tool for complex evaluations.

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Author Contributions

The authors of this paper all made proportionate contributions.

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Table 1.The characteristic function is represented in tabular format.

V	Y_1^a	Y_2^b	...	Y_δ^z
v^1	$X_{Z_\tau}(v^1, Y_1^{a_i})$	$X_{Z_\tau}(v^1, Y_2^{b_i})$...	$X_{Z_\tau}(v^1, Y_\delta^{z_i})$
v^2	$X_{Z_\tau}(v^2, Y_1^{a_i})$	$X_{Z_\tau}(v^2, Y_2^{b_i})$...	$X_{Z_\tau}(v^2, Y_\delta^{z_i})$
\vdots	\vdots	\vdots	\vdots	\vdots
v^σ	$X_{Z_\tau}(v^\sigma, Y_1^{a_i})$	$X_{Z_\tau}(v^\sigma, Y_2^{b_i})$...	$X_{Z_\tau}(v^\sigma, Y_\delta^{z_i})$

Table 2:Toddlers recommended amount of iron per day

Age Criteria	Everyday iron intake recommendations
Seven to Twelve months	11 milligrams
One to Three years	7 milligrams

Table 3: Method comparison table

Methods	Ranking of alternatives	Optimum solution
Jafar, Muhammad Naveed, et al [5]	$Nu_4 > Nu_2 > Nu_3 > Nu_1$	Nu_4
Algorithm-1	$Nu_4 > Nu_2 > Nu_3 > Nu_1$	Nu_4
Algorithm-2	$Nu_4 > Nu_2 > Nu_3 > Nu_1$	Nu_4

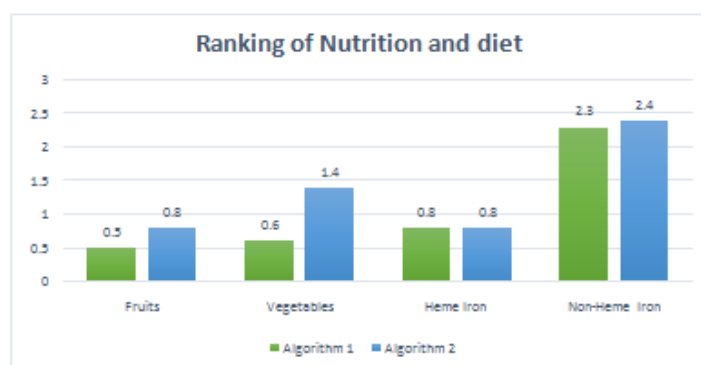


Figure 1: Ranking of nutrition and diet w.r.t. age and iron level of Toddlers'.





Assessment of Health - Seeking Behavior and its Barriers among Women with Breast Cancer

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ABSTRACT

In women, breast cancer is one of the leading causes of mortality. Health-seeking behavior refers to the sequence of remedial actions that individuals undertake to address perceived ill health. In this study, we propose to assess the health-seeking behavior among breast cancer patients and also evaluate the barriers encountered by breast cancer patients when seeking medical help. It is a cross-sectional observational study conducted among 212 breast cancer patients, utilizing the validated study tools Cancer Awareness Measure PLUS (CAM PLUS) and Breast-Cancer Awareness Measure (B-CAM) questionnaires. Questionnaires were distributed to participants, and the collected data were documented between March 2022 and July 2022. A substantial portion of the participants exhibited average health-seeking behavior and timely seeking medical assistance. A significant number of participants reported the absence of barriers, while others acknowledged encountering emotional and financial obstacles. Statistical analysis revealed a notable association between socioeconomic status, delays in health-seeking behavior, and barriers. Despite many participants accessing medical help promptly, some expressed concerns regarding their diagnosis and treatment processes. To address these barriers, educational initiatives regarding diagnosis and treatment are imperative for both patients and their family members.

Keywords: B-CAM; Breast cancer; CAM PLUS; Health-seeking behavior





INTRODUCTION

Breast cancer is one of the most common cancers and the leading cause of death in women [1]. According to various reports published in low- and middle-income countries like India, the incidence of breast cancer is increasing each year. In the year 2020, almost 178,361 new cases of breast cancer were reported, with more than 90,408 breast cancer deaths reported.[2] Most of the women were unaware of the early warning signs and symptoms of breast cancer, which resulted in poor screening rates and diagnosis at advanced stages[3-5]. Approximately, 70% of female patients exhibited delayed hospital arrivals, consequently exacerbating breast cancer mortality rates. Inadequate public awareness regarding breast cancer emerged as a primary determinant of delayed presentation and diminished survival probabilities[6,7]. Elevating women's breast cancer knowledge is crucial for overcoming these impediments. To effectively disseminate precise information and promote breast cancer awareness, it is imperative to conduct research into patient health-seeking behaviors that facilitate self-care and elevate health literacy levels[8-10]. However, there exists a paucity of research endeavors delving into the multifarious factors that underlie the deficiency in breast cancer awareness within the Indian population[11]. Hence, we proposed to conduct research on health-seeking behavior among women with breast cancer.

MATERIALS AND METHODS

Study design

This was a prospective cross-sectional study conducted in the Department of Radiology and Imaging Sciences at Sri Ramachandra Institute of Education and Research(Deemed to be university).The ethical permission to conduct the study was obtained from the Institutional Ethics Committee at Sri Ramachandra Institute of Higher Education and Research (DU) on 31/03/2022, with reference number **IEC REF: CSP/22/MAR/106/87**. This study enrolled female patients aged 18 years and older who had received a recent diagnosis of breast cancer, irrespective of the cancer stage. Patients who declined participation or had diagnoses of other cancer types were excluded. A total of 212 patients, meeting the inclusion criteria, were included in the study, and informed consent was obtained from all participants. Demographic information was collected by using a designed data collection form. The assessment of health-seeking behavior and the identification of barriers among breast cancer patients seeking medical assistance were evaluated using validated questionnaires, specifically the Cancer Awareness Measure PLUS (CAM PLUS) and the Breast-Cancer Awareness Measure (B-CAM).

CAM PLUS

The CAM PLUS questionnaire, developed by the International Cancer Benchmarking Partnership, is an established and validated tool for measuring public awareness regarding cancer symptoms, risk factors, and obstacles to seeking assistance. In addition to the original CAM questions, CAM PLUS incorporates new inquiries about cancer prevention, early diagnosis, and screening. It was employed as an instrument to assess the health-seeking behavior among breast cancer patients.

B-CAM

The B-CAM, developed in 2009 by Cancer Research UK, King's College London, and University College London, and validated with the support of Breast Cancer Care and Breakthrough Breast Cancer, is a survey instrument comprising seven domains. These domains encompass knowledge of breast cancer symptoms, confidence, skills, and behaviors related to detecting breast changes, anticipated delays in contacting a doctor, barriers to seeking medical assistance, understanding of age-related and lifetime risk factors, awareness of the NHS breast screening program, and knowledge of risk factors. For the present study, both the "CAM PLUS" and "B-CAM" questionnaires were employed to assess health-seeking behavior and barriers among women with breast cancer, and the responses were systematically documented and analyzed.





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STATISTICAL ANALYSIS

The data were analyzed using SPSS software version 23. Descriptive data were presented as numbers and percentages. The significance of relationships between socio-economic characteristics, delays in health-seeking behavior, and barriers was assessed using ANOVA, with a significance level set at $P < 0.05$, indicating statistical significance.

RESULTS

Baseline characteristics of the study participants

Out of the total number of participants, 28.77% fell within the age group of 26-35 years, 82.55% were married, and 59.43% were found to be literate. Approximately 49.6% of the participants were employed, and 64.15% of participants reported a household income above 50,000. Baseline characteristics are presented in Table 1. BIRADS scores of the participants were observed. 24.52 % of participants had a score of 2, 41.51% of participants had a score of 3, 12.28% of participants had a score of 4a, 7.54% of participants had a score of 4b, 6.13% of participants had a score of 4c, 7.55% of participants had a score of 5, 0.47% of participants had a score of 6.

Health-seeking behavior of the study participants

Approximately 34.90% of participants perceived the symptoms they experienced as unusual. About 27.35% of participants believed that the symptoms were indicative of cancer. An 18.86% proportion of participants acknowledged knowing someone who had experienced similar symptoms. Furthermore, 13.67% of participants reported that their symptoms persisted, leading them to seek medical help. Only 23.6% of participants mentioned that their family and friends encouraged them to seek medical assistance. Additionally, 21.7% of participants acquired information about breast cancer symptoms from various sources. Table 2 provides an overview of the health-seeking behavior exhibited by study participants. Given that participants could select multiple options, the maximum number of responses received was 5, with 3.77% of participants choosing over 4 options, indicating commendable health-seeking behavior. On the other hand, 80.66% of participants opted for 2 or 3 options, reflecting an average level of health-seeking behavior, while 15.56% of participants chose only 1 option, indicating suboptimal health-seeking behavior.

Delayed in seeking medical help

Out of the 212 participants, only 39.62% did not delay in seeking medical help. Approximately 22.16% of participants expressed concerns about the potential treatment process, while 7.07% of participants worried about the diagnosis process. Table 3 provides an overview of the delay in seeking medical help. Regarding the assessment of delayed health-seeking behavior, the highest number of responses observed was 4, with 2.35% of participants selecting all 4 options, indicating multiple reasons for their late presentation. About 25.47% of participants chose 2 or 3 options, suggesting fewer factors contributing to their delayed presentation. On the other hand, 72.16% of participants opted for just 1 option, indicating a very low likelihood of delayed presentation. There don't appear to be any grammatical errors in this passage.

Barriers to seeking medical help

Among the 212 participants, 7.54% reported feeling embarrassed to discuss their symptoms, while 20.75% expressed fear about visiting a doctor. Only 1.88% of participants indicated that they didn't seek help on time due to being busy. Remarkably, none of the participants considered language as a barrier, as depicted in Table 4. By calculating the total score for each participant, we assessed the level of barriers faced by the participants. A majority, 60% of participants, obtained scores between 31-33, indicating that they had not encountered significant barriers. Additionally, 36.8% of participants scored between 26-30, suggesting that they faced moderate levels of barriers. A small fraction, only 3.3% of participants, scored below 25, indicating that these individuals encountered a high level of barriers. There don't appear to be any grammatical errors in this passage.





DISCUSSION

Breast cancer stands as one of the most prevalent types of cancer affecting women on a global scale. Consequently, it becomes imperative to assess health-seeking behavior, the factors contributing to delayed presentation, and the barriers encountered when seeking medical assistance. These variables were evaluated among women recently diagnosed with breast cancer, regardless of the cancer stage. In this study, the age group of participants diagnosed with breast cancer was notably younger compared to the average age reported in another study, where the mean age of included patients was 48.2 ± 10.19 years [12]. In our study, the majority of the patients were married. A previous study has indicated that marital status and breast self-examination play significant roles in the seeking of treatment for breast cancer symptoms [13]. The majority of the participants were literate, and simultaneously, most of them reported that they never delayed in seeking medical help. Additionally, many of the participants faced a moderate level of or no barriers when it came to seeking medical help, especially when compared to uneducated or less educated women. This aligns with the findings of another study, which concluded that to reduce diagnostic delays, additional educational initiatives were required to enhance symptom awareness and address help-seeking barriers [14]. Breast cancer patients often lack knowledge about their illness and condition. One crucial factor in India and low- and middle-income countries is the lack of awareness and knowledge regarding breast cancer and the practice of breast self-examination. This lack of awareness is positively correlated with a woman's or her family's socioeconomic status, educational level, employment status, and marital status, as noted in a study [15].

In this study, nearly half of the participants were employed, and this often led to their inability to find time to seek medical help or take leave, resulting in delayed help-seeking behavior. The majority of the study participants had a household income above 50,000 rupees. Conversely, one-third of the participants reported facing significant financial barriers when attempting to seek medical assistance. This finding is in line with a previous study, which indicated that a significant number of breast cancer survivors believed that their diagnosis and treatment had a negative financial impact [16,17]. Among the participants in this study, we observed that some perceived their symptoms as unusual, while others attributed them to cancer. Additionally, some participants disclosed that they initially informed their family members about their symptoms and sought medical help with their support. Breast health awareness campaigns and family support can play a crucial role in encouraging women to prioritize their health and overcome feelings of fear and insecurity. These measures can be effective in addressing women's ambivalence towards seeking breast health care [18]. Family members and friends were cognizant of their responsibility in promoting and assisting with coping strategies among breast cancer patients [19]. Approximately one-third of the participants in our study did not delay in seeking medical help. However, others experienced embarrassment, lacked confidence in discussing their symptoms with their doctor, and had concerns about the diagnosis process and treatment. These factors were the primary reasons for their delayed presentation. It's worth noting that in a population-based study, African American women were found to experience the most delays in the initial diagnosis and the commencement of breast cancer treatment [20]. Awareness and knowledge regarding breast cancer and the practice of breast self-examination are of utmost importance. Additionally, it is recommended that specialized facilities be established within the public health system for early breast cancer diagnosis. The limitation of our study is that the responses provided by patients were self-reported, and there was no means to verify the accuracy of their responses. This may have led to over- or under-reporting of their responses. Furthermore, our study did not implement any educational initiatives.

CONCLUSION

This study comprehensively assessed various aspects of breast cancer, including health-seeking behavior, delays in seeking medical help, and barriers to seeking assistance. In terms of health-seeking behavior, the majority of participants exhibited an average level of behavior when it came to seeking medical help. Our research revealed that most participants did not delay seeking medical assistance. The educational levels and income of the participants played pivotal roles in their ability to seek help promptly. However, one-fourth of the participants expressed





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concerns about their treatment and visiting doctors in hospitals, in addition to their fears about the diagnosis process and financial barriers. To address these barriers effectively, it is essential to implement educational initiatives focusing on diagnosis and management for the general population. Overcoming emotional and financial barriers often requires the support of family members. Therefore, involving family members in awareness programs can be instrumental in eliminating barriers and reducing delays in seeking medical help.

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Table 1: Baseline characteristics of the study participants

Variables	Total no. of patients (n=212)	
	No. of participants	% of participants
Age in years		
18-25	26	12.26
26-35	61	28.77
36-45	50	23.60
46-55	42	19.82
56-65	16	7.54
Above 65	17	8.01
Marital status		
Married	175	82.55
Unmarried	37	17.45
Education		
No formal education	11	5.18
Secondary school	9	4.24
High school	52	24.52
Diploma	14	6.63
Degree and above	126	59.43
Employment status		
Employed	103	48.58
Unemployed	109	51.48
Household income		
20,000-30,000	15	7.07
31,000-40,000	26	12.27
41,000-50,000	35	16.51
Above 50,000	136	64.15

Table 2: Health-seeking behavior of study participants

S.No	Variables	% of participants (n=212)
3.	I had a symptom that was painful	6.6
4.	I knew someone who had similar symptom, and it turned out to be serious	18.86
5.	I had a symptom that didn't go away	13.67
6.	My friends or family encouraged me	23.60





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7.	I had a symptom, but I didn't know what was causing it	29.2
8.	I had a symptom that was "bothersome"	17
9.	I had a feeling that something wasn't right	22.16
10.	I had seen information about this symptom in the Media	21.7

Table 3: Delayed in health-seeking behavior

S.No	Variables	% of participants (n=212)
1.	I found it embarrassing talking about my Symptoms	8.5
2.	I had too many other things to worry about	17.45
3.	I worried about what they might find wrong	17
4.	I didn't feel confident talking about my symptom(s)	6.6
5.	I worried about what tests they might want to Do	7.07
6.	I worried about the possibility of having Treatment	22.16
7.	I worried about the impact on my employment from taking time off	12.73
8.	Nothing put me off/delayed me in seeking medical attention	39.62

Table 4: Barriers for seeking help.

S.No	Barriers	No. of participant (n=212)		
		Yes	Yes sometimes	No
		% of participants	% of participants	% of participants
1.	Too embarrassed to go and see the Doctor	7.5	16	76.42
2.	Too scared to go and see the doctor	20.7	25.5	53.8
3.	Too many other things to worry about	28.8	10.9	60.4
4.	Difficult to arrange transport	5.2	9.9	84.9





Effect of Muscle Energy Technique Along with Strengthening Exercise on Shoulder Function and Scapular Position in Upper Cross Syndrome

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ABSTRACT

Upper crossed syndrome (UCS) presents with weakened muscles in the neck, upper back, and shoulders, alongside tense areas, leading to altered movement patterns. This experimental study seeks to explore how muscle energy technique (MET) coupled with strengthening exercises affects shoulder function and scapular position in UCS. Key weakened muscles include the serratus anterior, middle and lower trapezius, rhomboids, and deep neck flexors, contributing to muscular imbalance and subsequent tightening or shortening of neck and chest muscles. In this study, 60 subjects diagnosed with Upper Crossed Syndrome (UCS) were separated as two groups: The Muscle Energy Technique (MET) group (n=30) and the Conventional group (n=30). The MET group underwent the muscle energy technique combined with 5 strengthening exercises, while the Conventional group received 5 conventional physiotherapy exercises. Assessment tools included the Shoulder pain and disability index (SPADI), Kibler's lateral scapular slide test, Craniovertebral angle, and Scapular index for pre and post-test evaluations. Both groups received interventions on alternate days for 3 weeks. The equipment utilized comprised a vernier caliper, a goniometer, and a resistance band. At the post-test, the mean value of the Muscle Energy Technique (MET) group combined with strengthening exercises surpassed that of the conventional group across all outcomes, exhibiting a significant p-value. The result concluded that MET





along with strengthening exercise shows a significant effect in improving shoulder function and scapular position.

Keywords: Muscle energy technique, Upper cross syndrome, cranio vertebral angle, kiblers lateral scapular slide test, UCS.

INTRODUCTION

Tightness and weakness in the neck, upper back, and shoulders are characteristic features of upper crossed syndrome (UCS), a disorder that causes abnormal muscle activation and movement patterns. While there are no specific diagnostic methods for UCS, this typically involves tightness in muscles such as the sternocleidomastoid, suboccipitalis, pectoralis major, upper trapezius, levator scapulae, and pec minor. On the other hand, muscles like the deep neck flexors, rhomboids, middle trapezius, serratus anterior, and lower trapezius tend to be stretched, weakened and inhibited.[1] Thoracic hyperkyphosis, cervical lordosis, stretched and elevated shoulders (rounded shoulders), forward head posture (FHP), and increased internal rotation accompanied by scapular winging and abduction are other postural disorders linked to UCS. People maintain this way of life until they are adults, and as we age, it just gets worse.[2] UCS is the term used to describe neck discomfort brought on by postural problems.[3] This condition is given the term "cross" because throughout the upper body is an "X" (a cross). Due to the normal development of a muscular imbalance between the muscles.[4] Adaptive shortening is the term used to describe the result of overusing a muscle in one way for an extended length of time leads to the shortening and tightening of the muscle. Stretch weakness, also known as elongation with weakening, results from the stretching of all antagonists.[5] The activation of the scapula muscles may change as a result, pattern of the movements, and a few abnormalities in the upper limb and In addition, the scapula, which connects the cervical and shoulder areas, plays a crucial role in regaining range of motion and support for the neck and shoulders.[6] Anxiety is one unwelcome emotion that is more likely to affect those who suffer from Upper Cross syndrome, and it can significantly lower their quality of life.[7] Multiple factors can lead to FHP such as using laptop for a prolonged period, while napping having your head elevated too for extended periods.[19] The only muscle that connects the scapula to the anterior side of the thoracic area is the pectoralis minor, which depresses the scapula.

Therefore, it is anticipated that the shortening of this muscle will limit the motion of the scapula in the superior and posterior directions.[8] To find out if someone has FHP, one can utilize the Craniovertebral Angle (CVA).[9] The angle formed by a horizontal line passing through the C7—a line and spinous process that runs from the middle within the tragus of the eardrum onto the layer of skin underlying it—is known as the craniovertebral angle. A CVA typically ranges from 48 to 50 degrees. FHP refers to any angle that is less than 48 degrees. Accurate evaluation of the FHP is necessary to assess the efficacy of therapeutic techniques.[10,11] Unbalanced soft tissue can put barriers in the way of the head's ROM and irritate the neck.[12] The shift in position from the original axis places extra strain on muscles to maintain the ongoing activity, which causes muscular deterioration.[13] Poor posture and bad habits are the primary causes of discomfort. UCS is a condition in which the muscles and other soft tissues become tense and movement is restricted.[14] In UCS, the head is positioned forward, which reduces the biomechanical effectiveness of the cervical non-contractile parts and forces the neck muscles to contract more actively to maintain cervical stability.[15] In a forward head position when seated, the lower cervical area is flexed, the upper cervical area is extended, and the shoulders are rounded. In upper cross syndrome, antagonistic muscle imbalances are the source of postural problems.[16] 6-48% of people with UCS experience shoulder girdle and cervicothoracic pain.[17] University students in particular, who were between the ages of 18 and 25, demonstrated a forward head stance and rounded shoulders, which is connected to UCS, in the proportions of 63.96% and 52.9%, respectively.[18] MET can extend shortened, contractured or spastic muscles; strengthen weaker muscles or groups of muscles due to physiological reasons; alleviate passive congestion, move immobile joints, and reduce localized oedema.[8] PIR, or post-isometric relaxation, is a method that involves isometrically contracting hyperactive muscles for a short while, followed by a



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brief latent period of relaxation to allow for gradual muscular lengthening. Due to changes in the muscle's viscoelastic properties, MET with PIR aids in reducing muscle tension and increasing muscle flexibility. MET is a sophisticated stretching method.[19] MET has the benefit of using the energy of the individual to generate physical activity that has a therapeutic effect.[20] Two fundamental effects of MET can be attributed to various physiological functions: Relaxation (RI) and post-isometric, reciprocal inhibition (RI).[21] The study's objective is to assess how well muscular energy techniques and strengthening exercises can help people with upper cross syndrome with their scapular posture and shoulder function.

MATERIALS AND METHODS

This study is experimental. The inclusion and exclusion criteria were used to choose 60 subjects in total. Participants in this study are between the ages of 25 and 50., both the genders. The participants were clinically diagnosed with upper cross syndrome. Written consent forms were obtained from the participants. Before providing their written consent, all subjects were informed in prior about the conditions of the experimental group and the procedures. Individuals with rounded shoulders (scapular index with vernier caliper), and individuals with forward head posture of CVA less than 48-50 degrees were included. Individuals with recent fractures or recent injuries or recent trauma of the upper limb and cervical spine, individuals with shoulder instability or any nerve lesions, individuals with any neurological symptoms like dizziness were excluded in this study. Vernier caliper, goniometer and resistance band are the materials used for this study. This study was approved by the institutional scientific review board [ISRB] [01/015/2023/ISRB/SR/SCPT]. Assessment tools included the Shoulder pain and disability index (SPADI), Kibler's lateral scapular slide test, Craniovertebral angle, and Scapular index for pre and post-test evaluations. SPADI is used to know the disability and shoulder pain range in subjects with UCS. It is divided into two sections: one for functional tasks and the other for pain. One hundred is the maximum attainable score.[24] This test assesses the shoulder blade's scapular posture, or protraction. In three distinct test postures (0°, 45° and 90°), Kibler developed a method for measuring scapular position.[25] Data analysis was conducted using the computed mean. 1.5 cm or greater difference in any of the three locations is regarded as a favorable LSST result.[26] In this study vernier caliper was used to take measurements and then mean values were calculated for all three positions in centimeters. CVA is used to assess forward neck posture. The CVA angle of less than 48 – 50 degrees is considered as forward head posture (reference) and subjects having less than this angle is included in this study.[27] Rounded shoulders were assessed by measuring scapular index. A digital vernier caliper was used to take both measures exactly.[28] By using the envelop method, The participants were divided into two equal groups. MET and conventional groups. Participants in the experimental group (n=30) were chosen, and the muscle energy techniques and strengthening exercises were performed. For three weeks and administered on 3 different days of the week. 30 minutes of three sets of 10 repetitions with 3-minute breaks.

muscle energy technique group

The MET is a manual treatment using voluntarily performed, regulated isometric contractions of a specific group of muscles. This technique is said to be beneficial for stretching a shortened muscle. So Muscle energy technique was given for 10 mins for all tight muscles including the levator scapulae, suboccipital muscles, upper trapezius, and pectoral muscles. For upper trapezius muscle the therapist gently flexed and rotated the sitting participant's neck to the other side until a slight stretching sensation was felt. For 7–10 seconds, the participant performed a normal isometric contraction (about 40% of maximal) against the therapist's hand in the opposite direction. After a brief relaxation of two to three seconds, the neck was passively stretched to its palpable limit or tolerance for 30 seconds. Following this, the neck relaxed in a neutral position for a brief 10-second period.[22] There were three repetitions of this process. In the last relaxation phase, the participant was told to breathe in and out. For suboccipital muscle the therapist positioned on the subject's head side while the subject lay supine. Both hands are placed on the C2 spinous process and the occiput area, respectively., the therapist identified the barrier causing the suboccipital muscles to contract. The subject was then instructed to inhale and perform an isometric contraction of the suboccipital muscles by resisting against the therapist's shoulder pressure while tipping their chin upward. The therapist applied



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resistance by placing the anterior portion of the shoulder on the subject's forehead. The subject exerted approximately 30% to 40% of their maximum force against the therapist's resistance for 10 seconds, followed by a 5-second rest period during exhalation. After the rest interval, the subject repeated the inhalation, followed by an exhalation during which the therapist stretched the suboccipital muscles for one minute. This sequence was repeated three times, with each set consisting of a 10-second contraction, a 30-second hold, and a 5-second rest period between sets. For the levator scapulae muscle in the supine position, the participant executed a sub-maximal isometric contraction for the levator scapulae muscle which was subjected to a PIR approach three times utilizing 30% to 40% of the maximum isometric contraction for 10 seconds. The stretch will last for thirty seconds and isometric contraction beyond the resistance of the therapist for about 10 seconds. During the last resting phase, the patient was told to breathe in and out to help with relaxation, 5-second rest interval was given.[23] For pectoralis minor muscle during MET (Muscle Energy Technique), the patient protracts their shoulder girdle while lying flat, exerting around 20% of their strength or matching the therapist's resistance. After holding this isometric contraction for 7 seconds while holding their breath, the patient relaxes and exhales. The therapist holds the stretch for 10 seconds as the patient relaxes and stretches the Pec minor to its new length. Every session, this procedure is performed at least three times, with a five-second break in between every repetition.

The strengthening exercise areas follows

For middle and lower trapezius strengthening (Table push) the participants stand close to the table and place their hands on its edge, slightly wider than shoulder-width. Keeping their body straight, they flex their elbows and bring their chest towards the table. They then push through the palms to return to the starting position. For serratus anterior strengthening (Wall slides) the participants stand with their back against a wall, positioning their elbows at a 90-degree angle and their arms at shoulder height against the wall. They then slowly slide their arms upward along the wall. For deep flexor strengthening (Chin tucks) after lying down, participants should softly tuck their chins into their chests while maintaining a level head. For shoulder retraction exercise stand straight with your shoulders at a 90-degree angle. Your forearms should be horizontal, and elbows flexed at 90 degrees. Grasp a portion of the workout band and pull back your shoulders, maintaining the 90-degree angles. Carefully return to the starting position. For shoulder External rotation during this exercise, ensure the upper arm and shoulder are at a 90-degree angle, with the elbow bend to 90 degrees. Start with the forearm horizontally and rotate it externally until vertical. Return to the beginning position slowly. Place the band in front of you at waist height to begin. Exercise will be given for 3 sets of 10 repetitions with 3 minutes rest between for 20 minutes for 3 weeks.

conventional group

In the conventional group (n=30) participants are selected. Five exercise were given for 3 sets of 10 repetitions with 3 minutes rest between for 30 minutes. For doorway stretch enter through an open gateway and extend each arm to the side with palms facing forward, bending them at a 90-degree angle. Press your hands against the door frame, adjusting elbow bend if needed. Move forward, maintaining an upright position without leaning. Hold for fifteen seconds, feeling the expansion in your chest and shoulders. For Rowing exercise using resistance band fasten it to a sturdy object at about hip height (a doorknob works well). The patient pulls the band using both upper limbs. For shoulder shrugging exercise participants stand on the floor with feet flat, then slowly inhale, bringing the shoulders as high up towards the ears as possible, and then lower the shoulders back down while exhaling. For shoulder squeeze exercise the participants stand or sit up straight, shoulders relaxed, hands at sides. Gently squeeze shoulder blades together without shrugging. Focus on muscles between shoulder blades as you squeeze. For shoulder bracing exercise the participants should overlap in front of the chest and elbows pointing outwards.

RESULTS

The values of the groups employing the muscular energy technique and conventional physiotherapy differed statistically considerable, according to a statistical analysis of the data. The MET group's pre-test mean was 46.00 (SD=1.46), whereas their post-test mean was 50.10 (SD=1.42), with a substantial rise from the pre-test mean of





$t=36.9702$ ($p<0.0001$). Similarly, the pre-test mean for the conventional group was 46.60 ($SD=1.75$), while the post-test mean was 47.97 ($SD=1.61$), with $t=15.2725$ ($p<0.0001$). The results are therefore regarded as highly statistically significant. (Table - 1) The post-test outcomes of the MET group and the Conventional group in CVA differ significantly. With $t=5.4426$ ($p<0.0001$), the Conventional group's mean value is 47.97 ($SD=1.61$), whereas the MET group's mean value is 50.10 ($SD=1.42$). The results are therefore regarded as highly statistically significant. (Table -2) The MET group's scapular index values significantly increased between the pre and post-test periods. $t=18.3984$ ($p<0.0001$), pre-test mean: 71.52 ($SD=2.17$), post-test mean: 74.82 ($SD=2.36$). A significant change from the pre-test mean of 71.30 ($SD=2.90$) to the post-test mean of 72.31 ($SD=2.95$) was also observed in the Conventional group, with $t=13.5218$ ($p<0.0001$). The results are therefore regarded as highly statistically significant. (Table -3) Significant differences are seen when the post-test results for the MET and Conventional groups are compared in terms of Scapular Index (SI). The mean values of the MET and Conventional groups are 74.82 ($SD=2.36$) and 72.31 ($SD=2.95$), respectively, with $t=3.6198$ ($p=0.0006$), suggesting extreme statistical significance. (Table - 4) Significant differences can be seen when comparing the MET group's pre-test and post-test readings. The mean scores are 54.23 ($SD=8.67$) for the pre-test and 37.63 ($SD=8.85$) for the post-test, with $t=23.6340$ ($p<0.0001$). For the Conventional group, the pre-test mean was 52.97 ($SD=7.96$), while the post-test mean was 44.43 ($SD=8.08$), with a significant change ($t=35.0845$; $p<0.0001$). They are both regarded as very statistically significant. (Table -5)

When the post-test results of the Conventional group and the MET group were compared, it was found that the Conventional group's mean value was 44.43, $SD = 8.80$, and $t = 3.1034$, whereas the MET group's mean value was 37.63, $SD = 8.85$. Therefore, when the p value equals 0.0029, the results are deemed statistically significant. (Table -6) Significant differences can be seen when comparing the MET group's pre- and post-test readings for LSST in three different positions: 0°, 45°, and 90° shoulder abduction. At 0°, the mean scores were 7.29 ($SD=0.89$) for the pre-test and 5.955 ($SD=0.07$) for the post-test, with $t=6.6406$ ($p<0.0001$). The pre-test mean at 45° was 8.57 ($SD=0.73$), the post-test mean was 6.64 ($SD=0.88$), and the t -value was 18.2759 ($p<0.0001$). The pre-test mean was 9.29 ($SD=0.71$) at 90°, the post-test mean was 7.54 ($SD=0.72$), and the t -value was 8.6516 ($p<0.0001$). The results are therefore regarded as highly statistically significant in each of the three degrees. Significant differences can also be seen when comparing the Conventional group's pre and post-test readings. $t=3.3938$ ($p=0.0021$), pre-test mean: 7.22 ($SD=0.78$), post-test mean: 6.51 ($SD=0.91$) at 0°. Consequently, the results are regarded as highly statistically significant. At 45°, $t=18.2655$ ($p<0.0001$), pre-test mean: 7.91 ($SD=0.68$), post-test mean: 7.11 ($SD=0.67$). $t=35.4329$ ($p<0.0001$), pre-test mean: 8.94 ($SD=0.85$), post-test mean: 8.02 ($SD=0.82$) at 90°. Consequently, in 45 and 90 degrees, the results are regarded as highly statistically significant. (Table -7) Significant changes can be seen when comparing the post-test results of the Conventional group and the MET group. The MET group mean was 5.95 ($SD=0.70$) and the conventional group mean was 6.47 ($SD=0.73$) at 0°. The t -value was 2.4530 ($p=0.0172$). The results are regarded as statistically significant as a consequence. $T=2.2897$ ($p=0.0257$), MET group mean = 6.64 ($SD=0.88$), Conventional group mean = 7.11 ($SD=0.67$), and 45° position. The results are regarded as statistically significant as a consequence. The MET group mean was 7.53 ($SD=0.71$), the conventional group mean was 8.02 ($SD=0.82$), and the t -value was 2.5116 ($p=0.0148$) in the 90° position. The results are regarded as statistically significant as a consequence. (Table -8) The study's results show that both Muscle Energy Technique (MET) with strengthening exercises and conventional physiotherapy significantly improved shoulder function, scapular position, and reduced forward neck and rounded shoulder posture. However, when comparing post-test results, MET with strengthening exercises proved to be more effective and significant than conventional physiotherapy. Therefore, MET with strengthening exercises is considerably more effective than conventional physiotherapy for UCS subjects.

DISCUSSION

This study's objectives include investigating how shoulder function and scapular position in upper cross syndrome are treated by the Muscle Energy Technique when combined with strengthening activities. Over the course of three weeks, this study is demonstrated. The Vernier caliper was used to measure the Scapular Index, the Lateral Scapular Slide Test (LSST) by Kibler and the CVA, and the SPADlating system. The CVA is used to measure forward neck



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posture, the Scapular Index (SI) for rounded shoulder, Kibler's Lateral Scapular Slide Test (LSST) for scapular position, and the SPADI scale for shoulder function, pain and disability. An early study by, Fizza Ali Syed 2022 et al, stated that the need of the study was to determine how the purported procedures affected the degree of pain, the degree of disability, and the limitation of ROM. The outcome demonstrates that the muscle energy strategy is superior to stretching exercises for treating individuals with upper cross syndrome, neck pain, and range of motion impairments. In 2014, Narang S. and colleagues carried out a study on thirty volunteers to assess the efficacy of deep neck flexor exercise in conjunction with muscle energy technique in patients with persistent neck discomfort who were positioned with their heads forward. When the research is finished, the results showed a considerable difference between A and B groups, indicating that MET in addition to DNF exercises was more beneficial than DNF exercises alone in reducing disability, enhancing discomfort, and adjusting forward head posture. The findings indicate that both groups' pain levels significantly improved, with the muscular energy approach demonstrating greater improvement than traditional therapy. In the Kim et al. study, which involved 44 participants, they looked at whether the craniovertebral angles of the Forward head posture groups with and without pain differed significantly. Their findings showed that the cervical vertebral angle values were considerably lower in the neck discomfort group. Additionally, the findings of their regression analysis that people with lower values of the CVA had a higher incidence of neck pain; hence, This angle was proposed as a sign of neck pain, which would contradict our findings.[29] An early study by Trivedi P, Sathiyavani D et al, They discovered that the active release Patients with chronic lateral epicondylitis showed improvement in grip strength and a reduction in discomfort and disability while using both the technique and the myofascial release technique.

However, MFR was superior than ART in individuals with chronic lateral epicondylitis in terms of lowering pain and impairment as well as enhancing grip strength.[30] Day JM and his fellow researchers found that range of motion (ROM) as a direct result of muscle energy method include a return to healthy range of motion (ROM), spontaneous strengthening of muscles that have been inhibited, a decrease in sympathetic overload, a reduction in localized irritation and the micro-edema that goes along with it, and an improvement in the structural and functional integrity of the entire movement chain.[31] This discussion is for upcoming research to explore the mechanisms of the MET, potential variations in treatment protocols, and the long-term outcomes of MET in patients with UCS. Kawaldeepkaur and his associates undertook a study in 2015. The groups who received the best treatment outcomes were those who received both traditional physical therapy and METs to increase ROM and reduce pain intensity. The data backs up the finding of our study, which shows that MET can effectively reduce discomfort at the spine of cervical.[32] Our research found that both the MET with strengthening exercises and conventional physiotherapy exercises, when applied alternately for three sessions, significantly improved shoulder function, and scapular position, and reduced forward neck and rounded shoulder posture. However, MET with strengthening exercises yielded superior results.

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Table 1:Comparing of Pre and Post-test values of MET group and conventional group in Craniovertebral angle.

CVA		Mean (Degree)	SD	T-Test	P Value
Muscle Energy Technique Group	Pre-Test	46.00	1.46	36.970	< 0.0001
	Post-Test	50.10	1.42		
Conventional Group	Pre-Test	46.60	1.75	15.272	
	Post-Test	47.97	1.61		

Compares the pre and post-test values of Muscle energy technique group. The mean value of the pre-test is 46.00 and the SD value is 1.46, Whereas the post-test mean value is 50.10, SD value is 1.42. $t = 36.9702$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 and Compares the pre and post-test values of the conventional group. The mean value of the pre-test is 46.60 and the SD value is 1.75, Whereas the post-test mean value is 47.97, SD value is 1.61, $t = 15.2725$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001.

Table 2: Comparison between the post-test values of Muscle energy technique group and Conventional group in CVA.

CVA		MEAN (degree)	SD	T-TEST	P-VALUE
Muscle Energy	POST-TEST	50.10	1.42	5.442	<0.0001





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Technique Group					
Conventional Group	POST-TEST	47.97	1.61		

Compares the post-test values of the Muscle energy technique group and the Conventional group in CVA, revealing that the mean value of the MET group was 50.10 and the SD value is 1.42, whereas the Conventional group mean value was 47.97 and the SD value is 1.61, $t=5.4426$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 .

Table 3: Comparison of Pre-test and Post-test Values of Muscle energy technique group and Conventional group in Scapular index (SI).

In Scapular Index (SI):					
SCAPULAR INDEX (SI)		MEAN (mm)	SD	T-TEST	P - VALUE
Muscle Energy Technique Group	Pre-Test	71.52	2.17	18.398	<0.0001
	Post-Test	74.82	2.36		
Conventional Group	Pre-Test	71.30	2.90	13.521	
	Post-Test	72.31	2.95		

Compares the pre and post-test values of Muscle energy technique group in SI. The mean value of the pre-test is 71.52 and the SD value is 2.17. Where as the post-test mean value is 74.82, SD value is 2.36. $t= 18.3984$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 and Compares the pre and post-test values of the Conventional group. The mean value of the pre-test is 71.30 and the SD value is 2.90, Whereas the post-test mean value is 72.31, SD value is 2.95, $t= 13.5218$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 .

Table 4: Comparison between the post-test values of the Muscle energy technique group and the Conventional group in SI.

SCAPULAR INDEX (SI)		MEAN (mm)	SD	T-TEST	P-VALUE
Muscle Energy Technique Group	Post- Test	74.82	2.36	3.6198	P value is equals to
Conventional Group	Post- Test	72.31	2.95		0.0006

Compares the post-test values of the Muscle energy technique group and the Conventional group in SI, revealing that the mean value of the MET group was 74.82 and SD value is 2.36, whereas the Conventional group mean value was 72.31 and the SD value was 2.95, $t=3.6198$. As a result, the findings are considered Extremely to be statistically significant when the p-value is equal to 0.0006.

Table 5: Comparison of Pre-test and Post-test Values of Muscle energy technique group and Conventional group in Shoulder Pain and Disability Index.

Shoulder Pain And Disability Index (Spadi)		MEAN (%)	SD	T-TEST	P -VALUE	
Muscle Energy Technique Group	Pre-Test	54.23	8.67	8.85	23.634	<0.0001
	Post-Test	37.63	8.85			
	Pre-Test	52.97	7.96			
Conventional Group	Post-Test	44.43	8.08	35.084	35.084	

Compares the pre and post-test values of the Muscle energy technique group. The mean value of the pre-test is 54.23 and the SD value is 8.67. Whereas the post-test mean value is 37.63, SD value is 8.85. $t= 23.6340$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 and Compared the pre and post-test values of the Conventional





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group. The mean value of the pre-test is 52.97 and the SD value is 7.96, Whereas the post-test mean value is 44.43, SD value is 8.08, $t = 35.0845$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 .

Table 6: Comparison of post-test values of Muscle energy technique group and Conventional group in SPADI.

Shoulder Pain And Disability Index (Spadi)		MEAN (%)	SD	T-VALUE	P-VALUE
Muscle Energy Technique Group	Post-Test	37.63	8.85	3.1034	P value is equals to 0.0029
Conventional Group	Post-Test	44.43	8.80		

Compares the post-test values of the Muscle energy technique group and Conventional group, revealing that the mean value of MET group was 37.63 and SD value is 8.85, whereas the Conventional group mean value was 44.43 and SD value was 8.80, $t = 3.1034$. As a result, the findings are considered to be statistically significant when the pvalue is equal to 0.0029.

Table 7: Comparison of Pre-test and Post-test Values of MET group and Conventional group in LSST.

LATERAL SCAPULAR SLIDE TEST(LSST)		MET GROUP(Cm)		CONVENTIONAL GROUP (Cm)	
		PRE-TEST	POST-TEST	PRE-TEST	POST-TEST
0Degree	MEAN \pm SD	7.29 \pm 0.89	5.95 \pm 0.70	7.22 \pm 0.78	6.51 \pm 0.91
	T VALUE	6.6406		3.3938	
	P VALUE	<0.0001		= 0.0021	
45 Degree	MEAN \pm SD	8.57 \pm 0.73	6.64 \pm 0.88	7.91 \pm 0.68	7.11 \pm 0.67
	T VALUE	18.2759		18.2655	
	P VALUE	<0.0001		<0.0001	
90 Degree	MEAN \pm SD	9.29 \pm 0.71	7.54 \pm 0.72	8.94 \pm 0.85	8.02 \pm 0.82
	T VALUE	8.6516		35.4329	
	P VALUE	<0.0001		<0.0001	

Compares the pre and post-test values of Muscle energy technique group. The mean value of the pre-test in 0 degree is 7.29 and the SD value is 0.89. Whereas the posttest mean value in 0 degree is 5.955, SD value is 0.07. $t = 6.6406$. As a result, the findings are considered extremely statistically significant when the p-value is <0.0001 . The mean value of the pre-test in 45 degree is 8.57 and the SD value is 0.73. Whereas the post-test mean value in 45 degree is 6.64, SD value is 0.88 and $t = 18.2759$. The mean value of the pre-test in 90 degree is 9.29 and the SD value is 0.71. Whereas the post-test mean value in 90 degree is 7.54, SD value is 0.72. $t = 8.6516$. As a result, the findings are considered extremely statistically significant in all three degrees when the p-value is <0.0001 and Compares the pre and post-test values of Conventional group. The mean value of the pretest 0 degree is 7.22 and the SD value is 0.78. Whereas the post-test mean value in 0 degree is 6.51, SD value is 0.91, $t = 3.3938$. As a result, the findings are considered very statistically significant when the p-value is = 0.0021. The mean value of the pre-test 45 degree is 7.91 and the SD value is 0.68, Whereas the post-test mean value in 45 degree is 7.11, SD value is 0.67, $t = 18.2655$. The mean value of the pre-test 90 degree is 8.94 and the SD value is 0.85, Whereas the post-test mean value in 90 degree is 8.02, SD value is 0.82, $t = 35.4329$. As a result, the findings are considered extremely statistically significant in 45 and 90 degree when the p-value is <0.0001 .

Table 8: Comparison between the post-test values of Muscle energy technique group and Conventional group in LSST.

LATERAL SCAPULAR SLIDE TEST(LSST)	MET GROUP(Cm)	CONVENTIONAL GROUP(Cm)
	POST-TEST	POST-TEST





0Degree	MEAN \pm SD	5.95 \pm 0.70	6.47 \pm 0.73
	T VALUE	2.4530	
	P VALUE	= 0.0172	
45 Degree	MEAN \pm SD	6.64 \pm 0.88	7.11 \pm 0.67
	T VALUE	2.2897	
	P VALUE	= 0.0257	
90 Degree	MEAN \pm SD	7.53 \pm 0.71	8.02 \pm 0.82
	T VALUE	2.5116	
	P VALUE	= 0.0148	

Compares the post-test values of the Muscle energy technique group and the Conventional group, revealing that the mean value in the 0 degree of MET group was 5.95 and SD value is 0.70, whereas the Conventional group mean value in 0 degree was 6.47 and the SD value was 0.73, $t=2.4530$. As a result, the findings are considered to be statistically significant when the p-value is equal to 0.0172. And the mean value in 45 degree of MET group was 6.64 and SD value is 0.88, whereas the Conventional group mean value in 45 degree was 7.11 and SD value was 0.67, $t=2.2897$. As a result, the findings are considered to be statistically significant when the p-value is equal to 0.0257. And the mean value in 90 degree of MET group was 7.53 and SD value is 0.71, whereas the Conventional group mean value in 90 degree was 8.02 and SD value was 0.82, $t= 2.5116$. As a result, the findings are considered to be statistically significant when the pvalue is equal to 0.0148.



Fig.1 MET for levator scapulae

The therapist performing the muscle energy technique. In the supine position, the participant executed a sub-maximal isometric contraction for the levator scapulae muscle which was subjected to a postisometric relaxation approach three times utilizing 30% to 40% of the maximum isometric contraction for 10 seconds. The stretch will last for thirty seconds and isometric contraction beyond the resistance of the therapist for about 10 seconds. During the last relaxation phase, the patient was told to breathe in and out to help with relaxation, 5-second rest interval was given.





Fig.2 shoulder retraction exercise

The experimental group participant performing shoulder retraction exercise as a strengthening exercise using resistance band. When performing this exercise, stand straight with your shoulder held out at a 90-degree angle in the plane of the shoulder. Your forearms should be horizontal and your elbows should be flexed at a 90-degree angle. To extend a workout band, grasp a portion on its longer side and pull back your shoulders. Keeping your elbows and shoulders at a 90-degree angle, carefully return to the beginning position.





	
<p>Fig.3 shoulder external rotation</p> <p>The experimental group participant performing shoulder external rotation exercise as a strengthening exercise using a resistance band. For shoulder External rotation during this exercise, ensure the upper arm and shoulder are at a 90-degree angle, with the elbow flexed at 90 degrees. Start with the forearm horizontally and rotate it externally until vertical. Return to the starting position slowly. Place the band in front of you at waist height to begin.</p>	<p>Fig.4 shoulder squeeze exercise</p> <p>The conventional group participant performing shoulder squeeze exercise. Participant stands or sit up straight with shoulders are relaxed and keep the hand at your slides and gently squeeze the shoulder blades together without shrugging the shoulder then focus the muscle between the shoulder blades as you squeeze.</p>





Successful Ayurvedic Management of Granulomatous Vocal Cord Lesion - A Case Study

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ABSTRACT

The Granulomatous vocal cord lesion is a non-neoplastic lesion that most often develops in the vicinity of the posterior vocal cords, adjacent to the vocal process. Present line of treatment in contemporary medical science is surgery followed by supplementary voice therapy. There are high chances of recurrence of the lesion after surgical excision. This report deals with a single case which was effectively managed with *Ayurvedic* intervention. A 48-year-old male patient presented with hoarseness of voice, cough, difficulty to produce high pitch notes since 3 months. Videolaryngoscopy was done and there was presence of Granulomatous vocal cord lesion. Treatment was done with *Pratimarsha nasya , kavala* ,oral medication along with voice rest. The hoarseness of voice and voice clarity improved on completion of the treatment. A repeat video laryngoscopy showed that the granulomatous lesion was no longer present. It shows the vocal cord Granulomatous lesion can be effectively managed with *Ayurvedic* intervention and recurrent rate also minimal.

Keywords: *Pratimarsha nasya , kavala* , *Ayurvedic* intervention, non-neoplastic lesion





INTRODUCTION

A 48-year-old male patient presented with hoarseness of voice, Cough, difficulty to produce high pitch voice, variations in pitch while talking and intermittent pain near the larynx area while speaking since three months. Prior to visiting our Hospital they had visited to near an Ear Nose Throat (ENT) specialist. On videolaryngoscopy, condition was diagnosed as Granulomatous vocal cord lesion and doctor was advised surgical excision. But patient being scared of the surgical procedure, Hence, the patient came for seeking Ayurvedic management in 2023 January.

PAST HISTORY-nothing significant.

FAMILY HISTORY-nothing significant

History of trauma-Absent.

Occupational history-LIC agent

ASTASTHANA PAREEKSHA

1. Nadi Pariksha -75/min
2. Mutra Pariksha-5-6/day
3. Mala Pariksha-1/day
4. Jihwa Pariksha-aprakrutha
5. Shabda Pariksha-prakrutha
6. Sparsha Pariksha-prakrutha
7. Drik Pariksha -prakrutha
8. Akriti Pariksha-madhyama

On examination

Nose: No any abnormality found

Ear: No any abnormality found

Throat: normal

Videolaryngoscopy was done which revealed [Figure 1]

- Presence of Granulomatous lesion on posterior end of vocal cord.
- Bilateral vocal cord mobile.

RESULT

Figure -02, 03, 04 – Result

After 3 days of treatment significant improvement was observed in hoarseness of voice with mild relief in throat pain. On Flexible fiberoptic endoscope examination, after 20 days of treatment, Size of Granulomatous lesion on posterior end of vocal cord size was decreased [Figure 3] and patient got complete relief from hoarseness of voice and coughing. The patient got improvement in fatigability in speech. On Flexible fiber optic endoscope examination, after 45 days the Granulomatous lesion on posterior end of vocal cord disappeared completely with normal colour of laryngeal mucosa [Figure 4] and patient was comfortable with frequent talks and high volume speech. significant improvement was observed in the symptoms and with the Ayurvedic therapy Granulomatous lesion of vocal cord completely resolved.

Fallow up-after 3month patient has contact with phone, there is no fresh complaints and also no voice problem.

DISCUSSION

Mode of action of drug





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TAB.SHIVAGUTIKA

- According to *Bhaishajya Ratnavali Shivagutika* action like *Indriyapradana*, *Oja-Teja balaprada* and *Rasayana*(1).
- And also Action like-Anti-inflammatory, Antitumor, Antioxidant and Immunobooster(2).
- So above said properties help to reduce the inflammation and size of the lesion .

TAB.KANCHANARA GUGGUL

- According to *Sharangdhar Samhita*, *Madhyam Khand*, *Kanchnaar Guggulu*(3)is having *Galaganda*, *Gandamala*, *Arbuda*, *Granthihara* and *Lekhaneeya* property(4)
- and also shows properties like Antimicrobial(5), anti staphylococcal activities(6), cytotoxic activity(7), antioxidant activity(8), anti-inflammatory(9) and analgesic activity(10).
- Any *kantagata roga* having tumour or inflammation we can use mainly *kanchanara guggulu* due this above said properties.

YASTIMADHU KSHEERA PAKA

- There is no specific refernce for *Yastimadhu ksheera paka*.but *Yastmadhu* is specially indicated for voice disorders due to its *Swarya* property which will improve voice tone and quality.
- *Ksheerapaka Kalpana* is a palatable medicament form with some modifications in *KwathaKalpana*(11)
- Preparation -One part of *Yastimadhu choornais* boiled in eight parts of milk with addition to thirty two parts of water.The boiling is continued till the added water gets evaporated and the original quantity of milk is left.(1:8:32)(12)
- It possess *Kanthyaswarya* as well as soothing effect that will improve the quality of voice as well as voice tone.It is *Rasayana* and *Snigdha*. It has anti-oxidant, anti-inflammatory, anti-ulcer and expectorant properties(13).

KAVALA

According to *Sushruta* when liquids can be moved to and fro in mouth is called *Kavala* while when mouth is completely filled with liquid so that it cannot be moved here and there is called *Gandusha*.

The medicated Kavala balances the PH and gets absorbed by increasing vascular permeability in oral mucosa. Thus it will help to reduce the inflammation and improve the disease healing process and proper salivary secretions.(14,15)

ANUTAILA

- Marsha nasya with *Anutaila* improves the voice and strengthens the functions of vocal cord. *Acharya Charaka* explained that *Nasya* with *Anuthaila* liquifies the *dosas* and extracts it out without destructing the site ,thus improving efficacy of *Indriya* (sense organs)(16).
- *Anutaila Nasya* has *Sheeta-Ushna Veerya*, *Katu Vipaka*, and *Tridosahara* properties. It promotes immune modulation which will reduce frequent episodes of inflammation(17) that restricts the reoccurrence of the lesion.

DISCUSSION

Granulomatous vocal cord lesion is also known as Vocal process Granuloma, is a nonspecific inflammatory process formed by granulation tissue that occurs primarily in the vocal process of arytenoid cartilage¹⁸. Etiopathogenesis of Granuloma is still undetermined and it is attributed to three predisposing factors: vocal abuse, laryngo-pharyngeal reflux disease (RLF) and laryngeal intubation.¹⁹ In present study the Granulomatous vocal cord lesion cause of is due to the overuse of voice because of the profession of the patient. The Hoarseness of voice or *kricchta* can be caused due to obstruction of the throat with *Kapha* and *Khara guna* of *Vata*. The treatment protocol was designed in keeping in mind the *Kapha Vata hara* principal. This single case report concludes that *Ayurvedic* management with *Pratimarsha Nasya* and *Kavala* procedure along with internal medicines, i.e. *tab.Shivagutika* and *tab.Kanchanara guggulu* and voice





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rest offers excellent result in the treatment of Granulomatous vocal cord lesion and improves patient's voice and brings it back to normal.

CONCLUSION

The videolaryngoscopy findings done before and after treatment reveals that the Granulomatous vocal cord lesion has been completely resolved with *Ayurvedic* intervention. *Ayurveda* can definitely play a major role in treating such conditions without any surgical procedures, Moreover surgical procedures may be a financial burden in addition to the psychological emotions. Hence more researches have to be concentrated on such diseases which can be treated therapeutically by *Ayurvedic* means where the western medicine has no option other than surgery.

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Table 1 –Treatment Protocol

S.N	PROCEDURE	MEDICATION AND DURATION
1	KAVALA	<ul style="list-style-type: none"> Kavala(gurgling) with Yastimadhu ksheera paka(sufficeint quantity) (3times per day)
2	PRATIMARSHA NASYA	<ul style="list-style-type: none"> Anutaila (2drops ,2times per day)
3	INTERNAL MEDICATION	<ul style="list-style-type: none"> Tab Shivagutika 500mg 1BD for 1month Tab.kanchanara guggulu 500mg 1 BD for 1month

Table 2 –Patya Apatya

S.N	Dos	Don'ts
1	advised for strict voice rest for the for 3 days and after that ,it was advised to less use of voice with minimum use of words	Ice cream, cold drinks, chocolate, fast food, talking with high pitch of voice and Long talk

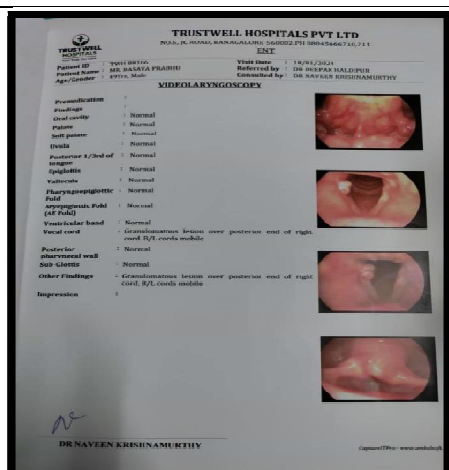


Figure 1-vediolaryngoscopy

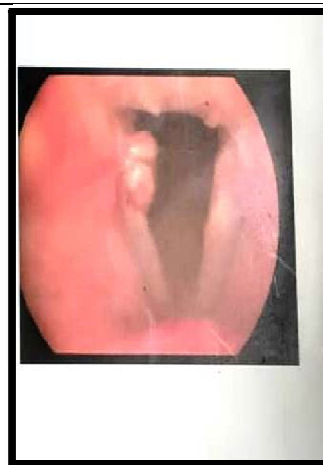


Figure 2- Before treatment

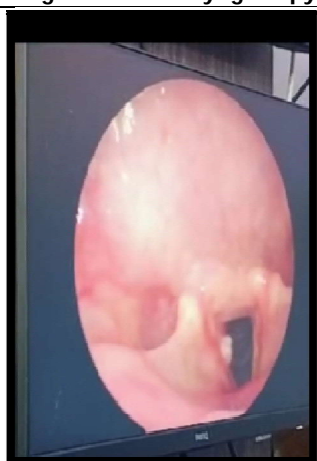


Figure 3-During treatment



Figure 4-After treatment





An Overview of Hazard Analysis Critical Control Points

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ABSTRACT

The most effective strategy for reducing biological (microbes and toxins), chemical, and physical risks is usually considered as HACCP. The danger or adverse impacts of hazards are assessed, predicted, and managed using technical and scientific methods. Hazard Analysis Critical Control Points (HACCP), a new method, has lately been adopted by the healthcare sector. That likelihood is meant to be reduced to a manageable level via HACCP. The HACCP (Hazard Analysis Critical Control Points) system is proposed in this study as a way to ensure food safety and hygiene in the pharmaceutical sector. HACCP seeks to avoid known risks and decrease the likelihood that they may materialize at particular stages of the pharmaceutical procedures. The government effort known as HACCP involves the FDA, WHO, GMP, GCP, and GLP. The goal of the current recommendations is to develop and put into action effective HACCP plans that address the development of products, sourcing of raw materials, production, packaging, testing, and distribution.

Keywords: HACCP, food safety, risk, FDA guidelines, HACCP plans.





INTRODUCTION

HACCP is a rigid, preventative, and proactive approach to product quality, reliability, and safety. It is a systematic procedure that makes use of technical and scientific principles to determine, avoid, and control the risk of hazards that may arise during the design, development, production, and use of products [1]. The objective is to make the product safely and prove that it was made safely. By analyzing and controlling physical, chemical, and biological risks associated with the creation, acquisition, and use of food safety is addressed by the HACCP management plan, which starts with the handling of raw materials and continues through production, distribution, and consumption of the finished product. A HACCP plan can only be successfully implemented if management is committed to the concept. A corporation with top management support for HACCP promotes in employees the value of creating safe food [2]. It is a process that is structured for studying, evaluating, preventing, and controlling the risk of hazards that occur from the creation, use, and maintenance of products. This strategy essentially seeks to plan out risky operations, in contrast to traditional "produce and test" quality control processes.

HACCP plan

A document created using the HACCP principles to ensure that risks important to pharmaceutical quality are controlled throughout the supply and manufacturing systems.

Critical Control Point (CCP)

A procedure that can be managed that is required preventing, eliminating, or reducing a risk to the quality of pharmaceuticals to a tolerable level. By validating important activities and procedures, dangers that affect quality are partially managed when final pharmaceutical products are produced utilizing Good Manufacturing Practices (GMP). While GMP does not address the safety of the manufacturing crew, HACCP addresses both safety and quality issues [3]. The HACCP system has been acknowledged as a practical and affordable method of assuring food safety. Today, this methodology is used across the entire production process and is recognized on a global scale as a tool for food safety [4]. To guarantee the high quality of the product, it is essential to employ a systematic strategy that involves the formation of a group of coordinated operations. There are numerous quality and safety-related methods used by Russian businesses: Occupational Safety and Health Management; a safety management system that complies with the requirements of the ISO 22000 international standard, with the HACCP plan serving as its primary component; GMP stands for "good manufacturing practice," GHP for "good hygiene practice," HACCP for "hazard analysis and critical control points," and ISO 9000 quality management systems.

Benefits of hazard analysis and critical control points

- ❖ The strategy focuses attention on the factors that have a direct impact on a product's safety
- ❖ At every step along the food chain, avoids the various shortcomings inherent in inspectional approaches, and gives a rational approach to the control of risks in foods.
- ❖ It increases consumer confidence in the food supply, and its adoption will lead to a larger market reach and reduced manufacturing costs (fewer recalls or food wastes).
- ❖ Its use reduces the possibility of acquiring food-borne diseases [6].

There are advantages to carry out the HACCP system

- ❖ To take a measure that will successfully shield food from threats like infection.
- ❖ To realize efficient utilization of labor and resources in order to achieve a more cost-effective production method.
- ❖ To improve the food's safety and quality and the practitioners' degree of hygiene management [7].

Limitation of hazard analysis and critical control points

The HACCP principle "establish critical limits" is the first restriction connected to the inability to link HACCP plans to public health objectives. Each CCP has one or more significant limitations that serve as the foundation for



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judgments about whether a process is under control or not. Our inability to clearly connect the conception and execution of HACCP systems to the influence they have on public health is a second, more significant restriction [8].

Potential areas of use

- ❖ HACCP can be used to determine and control the risks connected to microbiological contamination as well as physical, chemical, and biological hazards.
- ❖ When product and process expertise is thorough enough to support the identification of essential control points, HACCP is most beneficial [9].

Hazard analysis and critical control points history

HACCP initiatives first started as a logical extension of GMPs, which food industries had been utilizing as part of daily operations. For the National Aeronautics and Space Administration (NASA) to start using safe, nutrient-dense foods to feed future astronauts in the late 1950s, a system was required. While in space, food products could not be replaced or recalled. The Pillsbury Company started working with NASA in 1959 to further develop a method known as Failure Mode and Effect Analysis (FMEA), which was inspired by concepts used in engineering system development. Pillsbury and NASA determined the critical points in the process at which these hazards were likely introduced into product and should be controlled through the thorough analysis of production processes and identification of microbial hazards that were known to occur in the production establishment [10]. The HACCP system was initially introduced to the food sector in 1971 at a national conference on food safety. When in 1974, the FDA included HACCP guidelines to its low acid and acidified food standards. as a response to numerous incidents of poisoning caused by *Clostridium botulinum* contamination in commercially canned food, HACCP became a more widely used tool for some food manufacturers in the U.S. However, the widespread adoption of HACCP did not occur until the 1980s, when there were more outbreaks of food poisoning. At that point, several major food processing industries began using the technique. Published in 1985 was The National Research Council of the United States' evaluation on the importance of microbiological standards for foods and food ingredients[11, 12].

Three principles

- ❖ Identification and assessment of hazards
- ❖ Determining the important control points necessary to manage any identified hazards
- ❖ Establishment of systems to monitor critical control points[13].

Hazard analysis and critical control points and food regulation

The HACCP system is a high priority initiative under Codex Alimentarius, the global authority on food standards, and has also been applied in other nations that are governed by laws (such as Europe, Canada, Australia, and New Zealand). The HACCP approach has been widely adopted and legalized in many nations throughout the world, with successful outcomes for managing food safety. Early in 1990, the HACCP method was also introduced to China, however it mostly spread among some larger food businesses. For catering businesses, either the procedures were inadequately implemented or the results are insufficiently satisfying[14,15].

Prerequisite Programs

The necessary prerequisite programs must be in place before HACCP can be completely implemented because it is not a stand-alone program. Prerequisite programs, which are an essential component of the entire food safety strategy, are activities and/or conditions required before and/or during HACCP. Sanitary standard operating procedures (SSOPs), raw material control programs, vendor certifications, and good manufacturing practices (GMPs) and recall and trace back procedures are examples of typical preparatory programs. GMPs include things like sanitary facility design, appropriate pest management methods, and the availability and maintenance of hand washing stations and sanitary facilities. SSOPs may include guidelines for reducing cross-contamination within the facility, upkeep of a potable water supply, and particular procedures to guarantee the cleanliness of the facility. A foundation of successful preliminary programs is required for the adoption of HACCP[16,17].



**Kirthika Ravi et al.,****Sanitation standard operation procedures (SSOPs)**

SSOPs must be followed to ensure proper cleaning of surfaces that come into touch with products and those that don't. Raw materials, equipment, employees, personal hygiene, and food product handler practices are all covered by SSOPs. Food HACCP plans mandate that SSOPs be recorded and routinely reviewed. Professional and accountable management must do this SSOP review on a regular basis.

Standard Sanitation standard operation procedures guidelines are

- ❖ Raw materials for food must come from authorized sources and meet appropriate standards.
- ❖ To prevent cross contamination, hazardous or sensitive raw materials must be stored away from other raw materials at the right temperature.
- ❖ Food workers and operators must have access to gloves and hair restraints.
- ❖ Food handlers and operators must always have their permits on hand for inspection.
- ❖ Food handlers or operators should not be permitted to work in facilities where there is a possibility that they may be ill.
- ❖ In locations where food is produced, appropriate hand washing facilities are available and must be used.
- ❖ Making an effective sanitation protocol for operators to follow and choosing the right sanitizer. Work surfaces, tools, and equipment all require routine cleaning and sanitization.
- ❖ Verify sanitation effectiveness on a regular basis.

Good manufacturing practice (GMP)

GMP is a collection of operational standards that deal with both food safety and quality issues that are not essential for lowering the risks to food safety. Guidelines are also a crucial component of a good HACCP plan's formulation. To help lower the risk of food borne illness and ensure the production and distribution of safe foods of a quality fit for human consumption, these standards include direction for food manufacturing, sanitation protocols, testing methodologies, and quality assurance. Many nations adhere to GMP practices and have developed their own GMP standards that are in line with national laws.

In summary, Good manufacturing practice follow the following standard principles:

- ❖ Maintain a clean and sanitary environment in manufacturing locations.
- ❖ To avoid cross-contamination between food products, manage the environment.
- ❖ Create controlled, precisely defined production processes.
- ❖ Validate each critical control point (CCP) to guarantee the reliability and safety of the final product.
- ❖ Control the production process, and assess and validate any changes made to it.
- ❖ It is good documentation practice to explicitly write production instructions (production sheets) and record data for each process step as it is being manufactured.
- ❖ Reduce the possibility of food product contamination during distribution and delivery.
- ❖ Create a method for an immediate recall of any contaminated food distributed for sale[18].

Preliminary steps of hazard analysis and critical control points**Assemble of hazard analysis and critical control points team**

For the formulation of a successful HACCP plan, the food business should ensure that the necessary product-specific knowledge and experience are accessible. The best way to do this is to put together a multidisciplinary team. If such since there is a lack of knowledge, it should be acquired from external sources like trade and industry organizations, unaffiliated specialists, and regulatory bodies. The scope should state which link in the The basic categories of threats that must be handled include the threat to the food chain. Do all risk classes, or only part of them, are covered?



**Kirthika Ravi et al.,****Describe product**

It is important to create a thorough description of the product that includes all necessary safety details, such as its composition, physical/chemical makeup (including Aw and pH), Packaging, durability, storage conditions, microbial/static treatments (heating, freezing, brining, smoking, etc.), and distribution method.

State the desired usage

The desired usage is to be determined by the end user's or consumer's anticipated usage for the product. In some circumstances, it may be necessary to take into account vulnerable segments of the population, such as institutional feeding.

Construct flow diagram

The HACCP team should create the flow diagram, which should include every step of the process for a particular product. Numerous goods that are produced using similar processing methods can all share the same flow diagram. Steps before and after the indicated operation should be taken into account when applying HACCP to them.

On-site confirmation of flow diagram

During all phases and operational hours, Actions must be taken to compare the processing operation to the flow diagram and alter the flow design as appropriate. A person or people with sufficient understanding of the processing procedure should confirm the flow diagram[19, 20].

Directives for the hazard analysis and critical control points system's application

Regardless of the food chain, should have precursor programs like good hygiene practices in accordance with the essential Codex Codes of Practice, Codex General Principles of Food Hygiene, Codex Codes of Practice, and reputable food safety regulations in place before applying HACCP to that sector[21]. To assist the successful application and execution of the HACCP system, These HACCP-related programs, including the training component, should be well-established, confirmed, and in operation[22]. The impact of raw materials, ingredients, food manufacturing practices, the role of manufacturing processes to control hazards, When creating and implementing HACCP systems, hazards must be identified, evaluated, and dealt with in a manner that takes into account the product's likely end-use, at-risk consumer groups, and epidemiological data regarding food safety. The HACCP system's goal is to concentrate control at Critical Control Points (CCPs). If a danger that needs to be controlled is detected but no CCPs are located, the operation should be redesigned [23 , 24].

Implementation of hazard analysis and critical control points

To ensure the safety of medicinal products, the HACCP system detects likely risks. It is economical and results in less product loss and waste. By concentrating on the crucial aspects of the process, it improves the efficiency of the quality system. Instead than depending just on end product testing, it places more of an emphasis on prevention. By increasing consumer confidence in the safety of medicines, it can facilitate regulatory agencies' assessments, encourage international trade, and strengthen the viability of the industry. It complements and strengthens other quality management systems[25]. Some pharmaceutical industry could encounter common barriers or issues when implementing the HACCP system. Significant obstacles include a lack of knowledge and comprehension of HACCP regulations, technical failure, a lack of sources for HACCP information, a lack of employee involvement, and financial limitations. Employee awareness and understanding of the HACCP system was viewed as a major difficulty[26]. Other research' findings support the idea that most personnel in food production organizations are unaware of the HACCP system. The biggest concern as a barrier is a lack of staff commitment and engagement in HACCP implementation. Companies must create rules for all operations and control all manufacturing processes in order to comply with HACCP criteria[27,28].



**Kirthika Ravi et al.,****Maintenance of hazard analysis and critical control points plan**

The HACCP plan's establishment, operation, and verification records must be kept. Control over the HACCP plan record must match that over the system record. Relevant information must be included in a record of the HACCP plan. The following details must be included in the verification record at the very least:

- a) The following information is included in the product description record: plant name and address; processing category; the product's sort, name, dosage, and characteristics; the customer's intended use; the edible (use) method; the packing; the conditions for storage; the length of the warranty; the label's instructions; and the marketing and transportation regulations.
- b) Monitoring record: The monitoring record contains the following information: name of the plant, address, product name, processing date, CCP, significant hazard, critical limit (operation limit), control measure, monitoring method and frequency, actually measured or observed result, signature of the monitoring team, monitoring date, review reviewer's signature, and monitoring record date.
- c) Correction record: Name and address of the manufacturing facility; product name; processing date; description and cause of the deviation; corrective action taken; results obtained; batch; isolated location; assessment procedure; results obtained; and final disposal of the affected product; signatures of the corrective personnel; date of the correction; and date of the correction record.
- d) It is required to keep accurate records for the HACCP plan. The HACCP plan amendment record, the semi-finished product and completed product periodical inspection record, the CCP monitoring review record, the CCP rectification review record, and the CCP site verification record are a few examples of the primary records needed for verification activities.
- e) The HACCP coordinator should be in charge of authorizing revisions and ensuring that all required changes to the work instructions and HACCP plan are made. The plan and work procedures' previous iterations should be recalled and replaced with the new ones. When retraining is necessary, it should be done in accordance with the principles outlined earlier in this text. A crucial technique for ensuring that the HACCP plan is current and being executed on the plant floor is routine auditing. Following is a list of some of the elements that will be evaluated during these audits:
 - ❖ Is the flow diagram still an accurate representation of the line?
 - ❖ Are the raw material specifications and product formulation in accordance with the HACCP plan?
 - ❖ Since the HACCP plan was completed, has the line structure changed?
 - ❖ Are all of the work instructions, checklists, log sheets, and other documents needed to regulate and monitor CCPs accessible on the line? Do they have a purpose? Are they current?
 - ❖ Have all of the line workers received the necessary training, and do they all recognize the value of HACCP?[29].

Training

For HACCP to be implemented effectively, industry, government, and academic people must be trained in its concepts and applications, and consumer awareness must be raised. Working guidelines and protocols that outline the duties of the operational personnel assigned to each Critical Control Point should be prepared as a tool to support the development of particular training to support a HACCP plan. Primary producers, business, trade associations, consumer advocacy groups, and accountable authorities must work together. Opportunities for combined training between industry and control authorities ought to be made available in order to promote ongoing communication, foster mutual understanding, and advance the actual implementation of HACCP^{30,31}.

Hazard analysis and critical control points principle**The seven principles are**

1. Conduct a hazard analysis.
2. Determine the critical control points (CCPs).
3. Establish target levels and critical limit(s).
4. Establish a system to monitor the CCPs.
5. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.



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6. Establish procedures to verify that the HACCP system is working effectively.
7. Establish documentation concerning all procedures and keep records appropriate to these principles and their application[32].

Principle 1: Conduct a hazard analysis

Create a flow diagram that details all handling/preparation stages for a given menu item in order to identify the hazards connected with that item. Once the process flow confirmation has been developed, the HACCP team must evaluate individual hazards at each stage of product manufacturing, testing, and distribution. Safety and quality concerns must be separated when performing a hazard analysis. A biological, chemical, or physical agent that, in the absence of control, presents a danger of illness or injury is referred to as a hazard. The plan won't work no matter how well it is implemented if the HACCP system does not identify the risks that require control and the hazard analysis is done incorrectly. There are two stages to conducting a hazard analysis. The first step, identifying hazards, could be compared to a brainstorming session. The HACCP team examines the product's ingredients, the steps and tools used at each stage of the process, the finished item and how it is stored and distributed, as well as the intended use and intended consumers, during this stage³³. The second stage, known as the hazard evaluation, is carried out following the creation of the list of probable dangers. The HACCP team determines which potential hazards need to be addressed in the HACCP plan during stage two of the hazard analysis. Each potential risk is assessed at this point based on how serious it is and how probable it is to occur. The seriousness of the effects of exposure to the risk is referred to as severity. The seriousness of the effects of exposure to the risk is referred to as severity. The food, its preparation process, transportation, storage, and the people who will likely consume the product should all be taken into account when evaluating each potential hazard to see how they might affect the likelihood and severity of the threat being mitigated. The group must consider the effects of anticipated food preparation and storage procedures as well as if its target demographic is more susceptible to a potential hazard[34]. Conducting a two-stage risk analysis is advised. Making a list of potential risks for each step could be the first step. The thorough risk assessment will contain

- ❖ significant risks and their potential sources
- ❖ The risk that a hazard will develop in the absence of suitable controls.
- ❖ A basis for determining if the risk merits inclusion in a subsequent HACCP assessment[35].

Principle 2: Determine the critical control points (CCPs)

Using control to prevent, remove, or reduce a risk to an acceptable level for food safety is known as a critical control point (CCP). It is necessary to address any serious hazards found during the hazard analysis[36]. Food safety risks are recognized at various points or steps in the process that need to be adjusted. It is crucial to totally and precisely identify CCPs in order to reduce the hazards to food safety. The HACCP team needs the data generated during the hazard analysis to determine which process steps are CCPs. At every level where a control must be put in place to mitigate the same risk, there might be more than one CCP. A more effective and appropriate method for reducing the number of CCP is to use a decision tree, which encourages a logical approach. Critical control points for preventing each of the mentioned hazards are noted. Critical control points are those parts of the process where losing control could pose an unacceptable danger to health. To guarantee the product's safety, these criteria must be kept under control. After a product has been processed, careful temperature control may be one important control point[37]. At every level where a control must be put in place to mitigate the same risk, there might be more than one CCP. A more effective and appropriate method for reducing the number of CCP is to use a decision tree, which encourages a logical approach. Each processing step where a risk exists is the subject of a series of questions asked using the decision tree method. The answers to these questions, which are presented in a yes/no format, eventually determine whether a given step is considered CPP or not. If the hazard has been identified, its control is necessary, and there are no control mechanisms in place, one must be created[38].



**Kirthika Ravi et al.,****Principle 3: Establish target levels and critical limit(s)**

A CCP needs to limit a biological, chemical, or physical feature to a maximum and/or minimum value in order to avoid, remove, or reduce the incidence of a risk to food safety to a manageable level. Crucial boundaries are determined based on regulatory action levels or historical data. There are times when more than one crucial limit is needed at a certain moment. A critical limit is used to distinguish between safe and harmful operating conditions at a CCP. The HACCP team must use prudence when establishing critical limits that are as realistic as possible for the process in question. Setting important limitations helps with the implementation of an effective monitoring and control system. Critical limitations should not be confused with operational limits, which are set for reasons other than maintaining the safety of food. To ensure that the risks identified are minimized, addressed, or reduced to manageable levels, each CCP will have one or more controls. While some crucial boundaries may be outlined in laws, codes of conduct, and guidelines, others may require experimental evidence to be gathered or cited, or guidance from experts with specialized knowledge.[39,40].

Principle 4: Establish a system to monitor the critical control points

A set sequence of observations or measurements is known as monitoring. Its goals are to ascertain whether a CCP is under control and to produce an accurate record that can be verified afterwards. Three key objectives are served by monitoring. First, monitoring is crucial for managing food safety since it makes it easier to keep track of the process. Action can be made to regain control of the process if monitoring shows a tendency toward loss of control in order to prevent a breach of a crucial threshold. Second, monitoring is used to determine whether a CCP experiences a loss of control and a diversion, or when a critical limit is either exceeded or not fulfilled[41]. As a result, it's crucial to completely outline how, when, and by whom monitoring is to be carried out. A suitable remedial action must be implemented when a deviation occurs. Thirdly, it offers textual evidence that can be used for verification. It is necessary to define specific monitoring protocols for the important control point(s). Without a precise strategy for gathering data on the key control point, having a maximum temperature for a control point is of limited use[42] If the safety of a product depends on the addition of acid, then the pH or acid content limitations must be established and tracked. A designated individual with the knowledge and power to implement remedial actions when necessary must evaluate the monitoring data. If monitoring is not continuous, it must be done frequently or in significant amounts to ensure that the CCP is under check. Line supervisors, maintenance employees, and, where necessary, members of the quality control team should all be involved in production while monitoring CCPs and control measures. They ought to receive training on monitoring techniques. A trustworthy monitoring process and frequency should be determined where continuous monitoring is possible. Then, mechanisms for gathering data or doing sampling should be statistically developed. All records and papers pertaining to the monitoring of CCPs must be signed and dated by the person(s) conducting the monitoring and the responsible reviewing official(s) of the company. Either continuously or very rarely, the crucial limit is being observed. It is possible to design a computer system for periodic measuring. A person will need to keep an eye on or even frequently calibrate this device to ensure that it operates effectively. When the use of sporadic monitoring is used, industry workers must conduct frequent inspections[43].

Principle 5: Establish the corrective action to be taken when monitoring indicates that a particular critical control points is not under control

The correct procedures must be performed when a vital threshold is crossed without error (a process variation). Corrective actions that are both long-term and short-term can be taken. The proper records must be kept. To address deviations when they happen, Each CCP in the HACCP system requires the creation of specific corrective measures. The CCP must be brought under control as a result of the acts. The contaminated product must be properly disposed of as part of the actions performed. Procedures for handling deviations and discarding products must be included in the HACCP records. Plant management must make a strategy in advance to address anticipated deviations from defined critical limits because HACCP is a preventive system to address issues before they influence food safety. When a critical control point limit is surpassed, the plant must act right away to fix the situation. The corrective action must be decided upon in advance by the plant management. The staff members in charge of keeping an eye on



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the crucial control point have to be trained in this procedure and have a thorough understanding of it. Corrective actions should preferably involve the consideration of:

- ❖ the present, i.e., what is going to happen immediately in the production operation and how can control be regained, which may include an investigation of what went wrong,
- ❖ the past, i.e., what is going to be done with the product if it is judged to be non-conforming, that is out of specification in terms of safety and/or quality criteria,
- ❖ the future, i.e., how to prevent loss of control from happening again in the future,
- ❖ who is to act and has responsibility and authority for the actions taken, and
- ❖ the record to be taken[44,45].

Principle 6: Establish procedures to verify that the HACCP system is working effectively

Verification is described as the processes that, Along with monitoring, make sure the HACCP plan is accurate and that the system is operating in compliance with it. A HACCP strategy requires verification in four stages:

1. Verify the soundness of the critical limits at all CCPs.
2. Verify that the HACCP plan is being effectively executed at the establishment.
3. In order to ensure that the plan is being implemented correctly, regulatory personnel should review it.
4. Verify that all monitoring equipment is accurate[46].

The effectiveness of the HACCP system can be assessed using verification and auditing techniques, protocols, and tests, such as random sampling and analysis. The HACCP system's effectiveness should be confirmed by the frequency of verification, which should be sufficient.

Examples of verification activities include:

- ❖ review of the HACCP system and its records;
- ❖ review of deviations and product dispositions;
- ❖ Confirmation that CCPs are kept under control.

First, the HACCP plan must be verified to confirm that it is technically and scientifically sound, that all dangers have been identified, and that, if the HACCP plan is correctly executed, these hazards will be successfully controlled⁴⁷. Additionally, a routine thorough assessment of the HACCP system by a dependable, impartial outsider is beneficial. In addition to an on-site examination of all flow diagrams and the pertinent records of the plan's a technical assessment of the hazard analysis and each HACCP plan component should be included. It is necessary to do such a thorough verification, which is independent from other verification processes, to confirm that the HACCP plan is successfully reducing the risks. The HACCP team should make the necessary modifications to the HACCP plan if the findings of the thorough verification reveal any flaws. Although validation reveals that the company performs what it intends to do in order to ensure that the HACCP plan is followed, verification verifies that this is the case.⁴⁸.

Principle 7: Establish documentation concerning all procedures and keep records appropriate to these principles and their application:

During the HACCP study, documentation will contain process flow diagrams and tables (records of the creation and monitoring of HACCP plans). The deployment of a HACCP system depends on effective and accurate documentation and record keeping, which should be adequate for the nature and scale of the operation. Without records, there will be no proof that a plant follows the HACCP plan's instructions. Records can be consulted to spot patterns and improve a process over time. Processes including hazard assessment, CCP determination, HACCP plan creation, and crucial limiting procedures all require documentation[49]. Examples of activities for which documentation is required include:

- ❖ hazard analysis;
- ❖ CCP determination;
- ❖ HACCP plan;
- ❖ Critical limit determination.



**Kirthika Ravi et al.,****A HACCP plan's records include the following:**

- ❖ A list of the HACCP team's members and their respective roles
- ❖ Each menu item should have the following: a description, a flow diagram showing the CCPs for each item, hazards and preventive measures, critical limits, monitoring protocols, and corrective action plans.
- ❖ Record-keeping processes HACCP plan verification procedures
- ❖ Finally, it is very important to have procedures for verifying that the HACCP plan is being followed and that it working according the plan[50].

Barriers or challenges to successful implementation of hazard analysis and critical control points

1. Due to the lack of enough resources, practical knowledge, and qualified employees for HACCP execution, small to medium-sized pharmaceutical organizations may find it difficult to adopt HACCP, but comparatively large companies may find it easier[51,52].
2. Lack of motivation and oversight - Maintaining the HACCP system's functionality depends heavily on staff motivation. Staff supervision is crucial at every level for the proper operation of HACCP. The HACCP system's dedicated workforce plays a significant role in implementing and maintaining the HACCP framework, particularly with regard to the demands for ongoing surveillance and reporting.[53].
3. One of the main challenges brought on by the lack of employee training for HACCP is the lack of workers with expertise and awareness of the system. Typically, training sessions are designed with specific staff members or groups in mind, taking into account their level of technical expertise and level of responsibility throughout the HACCP process. This enables staff to apply the HACCP idea to their particular processes[54,55].
4. Small pharmaceutical companies typically lack the purchasing power to support HACCP implementation costs, and they are also frequently unable to persuade or effectively pressure their suppliers to adopt the HACCP system[56].

Advantages of hazard analysis and critical control points implementation in the pharmaceutical industry

- ❖ The benefits of applying HACCP include maximizing resource efficiency and providing quick fixes for product safety issues in addition to raising the safety of pharmaceuticals.
- ❖ HACCP reduces the amount of required end product laboratory testing, the number of non-compliant products, and even the number of required sample plans for process control.
- ❖ Due to documenting and record keeping, HACCP can help regulatory bodies with inspections. Additionally, by increasing consumer confidence in the safety of medicines, it promotes both firm stability and international trade.
- ❖ HACCP increases the effectiveness of the quality system by highlighting key components of a method and focusing on preventing problems rather to relying solely on assessing the final output[57].

DISCUSSION

In our article, we focused on how to identify industry challenges to HACCP and food safety procedures. One of the main barriers to the application of HACCP is a lack of knowledge and understanding. It is vital to remember that HACCP is a management tool and that merely enacting HACCP guidelines does not ensure food safety. As conclusion, lack of knowledge and other food safety programs were determined as the main barriers to food safety in food businesses. Lack of prerequisite programs and the inadequate physical condition of the facility were also identified as other barriers. It is suggested that tools like HACCP must be employed in pharmaceutical companies to prevent losses and product rejections owing to poor quality. HACCP must be properly developed, efficiently implemented, and continually reviewed and improved for it to be effective in a facility's handling or processing of food.



**Kirthika Ravi et al.,****ACKNOWLEDGEMENT**

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Conflict of interest

The Author declares that they have no conflict of interest.

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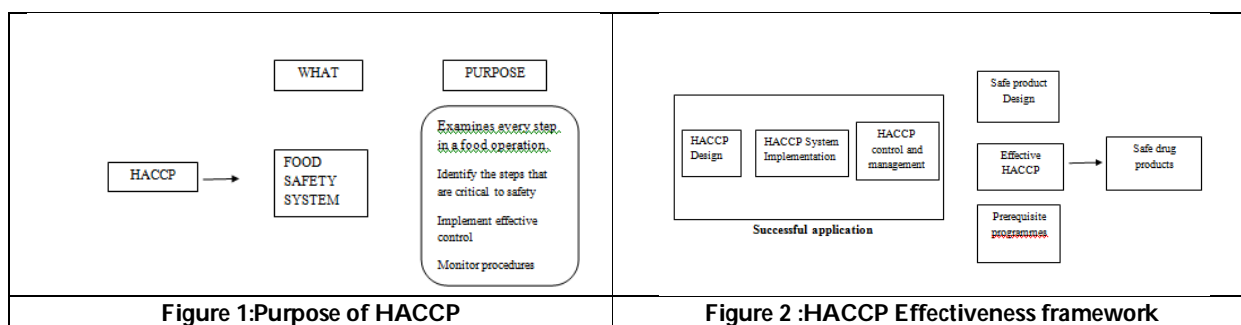
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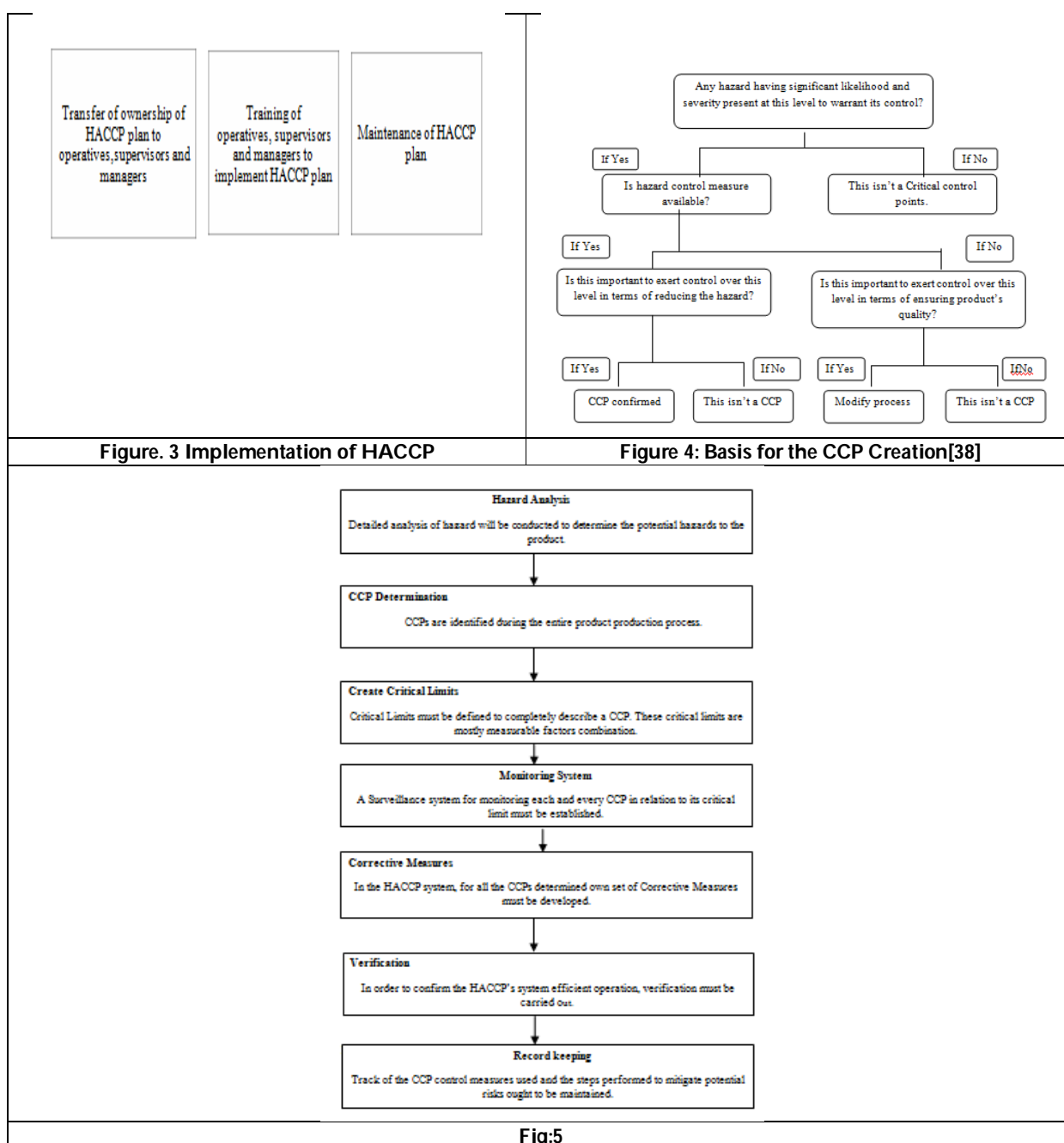




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A Mathematical Investigation of the Improvement of Heat Transport through a Variety of Nanofluids

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ABSTRACT

The mathematical model of nanofluid thermal conductivity has been discussed in this research. The issues this study seeks to answer will help researchers gain a better understanding of what influences the thermal conductivity of nanofluids. When it comes to the other two, nanolayer Research also takes into account the thickness and diameter of the nanoparticles. Changing just one factor while keeping the others the same produces the desired result. Thicker nanolayers were thought to have higher heat conductivity. There were measurements made of the thickness of a water and ethylene glycol nanolayer. Graphs displaying the calculated thermal conductivities of a variety of nanofluids are provided. Visualizations and numerical calculations of heat transfer coefficient versus volume fraction for varying Reynolds and Prandtl numbers. As the heat capacity ratio increases, heat exchangers become more efficient and effective.

Keywords: Thermal Conductivity, heat transfer coefficient, pumping power, performance index, specific heat





INTRODUCTION

The need for high-efficiency engines has grown as automobile technology has advanced. Lightening the load on vehicles is essential to achieving environmental sustainability, hence optimizing radiator design and size is essential. Adding fins to a radiator is one way to speed up its cooling time. But the standard approach, which makes use of fins and microchannels to speed up the cooling process, can only go so far. Water and ethylene glycol, two popular heat transfer fluids, have a relatively low thermal conductivity. Therefore, the development of novel heat transfer fluids capable of significantly boosting the efficiency of a vehicle's cooling circuit is of the utmost importance. Nanofluids could one day replace traditional coolants in vehicle engines. Several recent investigations have shown that nanofluids excel at heat transmission. Adding nanoparticles to a base fluid like water, ethylene glycol, oil, or air can increase the fluid's thermal conductivity, allowing it to be used in a number of situations where the weak thermal conductivity of regular liquids would be a hindrance. The added nanofluids significantly improved the base fluids' thermal conductivity. The nanofluid thermal conductivity must be evaluated with the original goal of measuring this improvement in mind. To create the basic fluid, we combined equal parts water and ethylene glycol. Nanoparticles can be used to improve a coolant's heat transfer efficiency by increasing its surface area for heat transmission. To achieve optimal heat transfer, however, the concentration of Al_2O_3 and CuO nanoparticles must be established. Because of the complexity of its geometry, there are less publicly available explorations of this air cooler arrangement, which consists of louvered fin and flat tube. Now, conventional liquids like water, ethylene glycol, and oil are being used to create a new category of fluids known as nanofluids, thanks to advances in nanotechnology that have enabled the synthesis of a wider variety of nano-scale materials. It is proposed that nanoparticles be studied in combinations of water and liquid catalytic materials (as the base liquid) utilized in automobile radiators.

Several compounds are sometimes added to the water in a car's radiator to keep it from freezing or boiling over in extremely cold or hot weather. It prevents the radiator fluid from freezing during the winter and the automobile from overheating during the summer. Glycols make up the vast majority of these auxiliary chemicals, EG in particular. Automobile radiators, computer fluid cooling systems, chilled water cooling systems, and so on are typical examples of convective heat transfer methods that make use of EG. Since water is a more efficient motor coolant, it has been combined with EG. The issue with water is that at very high temperatures, it either ceases to move or begins to bubble. When EG is added to water, it significantly improves the liquid's resistance to freezing. Although water and other liquids can be used as coolants, the true power to withstand high temperatures is found in the radiator fluid. The impact of heat source type and position on flow and heat characteristics of flow within enclosed cavities was studied by Oztop et al. (2015), who looked at research that used two- and three-dimensional computational analyses in addition to experimental methodologies. Alkhalidi et al. (2016) ran simulations with different values of the conductivity ratio, Rayleigh number, and cavity tilt angle to see how the system would react. Al-Kouz et al. (2018) found that by adding Al_2O_3 nanoparticles to a low-pressure gaseous flow at the system's base, heat transfer was enhanced. In a numerical study, Al-Kouz et al. (2018) examined how the Knudsen number, Rayleigh number, porosity, location, length, tilt angle, and conductivity ratio affected low-pressure flow and heat transfer in an inclined enclosed cavity. They linked these other parameters to the Nusselt number. Radiator coolant nanofluids made from water and antifreeze were evaluated by Geetha and Sudhakar babu (2019). Using magnetic nanofluid (Fe_3O_4 suspended in water), Abdulwahab et al. (2020) demonstrated how fluid flow and heat transfer could be improved inside square, circular, and triangular straight channels with a hydraulic diameter of 0.01 m, regardless of the presence or absence of magnetic fields. In a comprehensive review, Oudina and Chabani (2022) discussed the exciting scientific progress made in the area of heat transfer improvement. Mohamed et al. (2023) investigated how varying the Al_2O_3 nanofluid concentration from 0.05% to 0.4% by volume, the nanofluid mass flow rate inside the tube, the water flow rate via the annulus, and the inlet temperature inside the tube affected the Nusselt number. Both the nanoparticle concentration per unit volume and the Reynolds numbers of the flows inside the tube and through the annulus were found to enhance the Nusselt number and the friction factor.



**Mathematical Formulation**

Thermal conductivity in $W/m.K$ given by Purohit *et al.* (2016) is

$$k_{nf} = \frac{k_p + 2k_{bf} + 2(k_p/k_{bf})\phi}{k_p + 2k_{bf} - (k_p - k_{bf})\phi} \quad (1)$$

Where ϕ denotes the nanoparticles' proportional share in the volume.

Wang *et al.* (2008) has given the formula for density in kg/m^3

$$\rho_{nf} = (1 - \phi)\rho_{bf} + \phi\rho_p \quad (2)$$

The formula for specific heat $J/kg.K$ given by Khanafer *et al.* (2011) as

$$c_{nf} = \frac{(1-\phi)\rho_{bf}c_{bf} + \phi\rho_p c_p}{\rho_{nf}} \quad (3)$$

The expression for viscosity ($kg/m.s$) due to Batchelor *et al.* (1977) is

$$\mu_{nf} = (1 + 2.5\phi + 6.2\phi^2)\mu_{bf} \quad (4)$$

For coolant-side, the heat transfer coefficient can be expressed as:

$$h_{nf} = \frac{Nu_{nf}k_{nf}}{D_{nf}} \quad (5)$$

Where D_{nf} is diameter of nanofluid.

The experimental results were used to establish a correlation that allowed us to predict the Nusselt number of the silver-water nanofluid with an accuracy of within 10%.

$$Nu_{nf} = 0.023Re_{nf}^{0.8}Pr_{nf}^{0.3} + (0.617\phi - 0.135)Re_{nf}^{0.445\phi - 0.37}Pr_{nf}^{(1.081\phi - 1.305)} \quad (6)$$

Nusselt number for base fluid has been calculated by

$$Nu_{bf} = \frac{f_f Re_{bf} Pr_{bf}}{\sqrt{2[1.07\sqrt{2} + 12.7\sqrt{f_f}(Pr_{bf}^{2/3} - 1)]}} \quad (7)$$

The coefficient of friction has been determined by calculation from

$$f_f = (1.58Re_f - 3.28)^{-2} \quad (8)$$

The Prandtl number of the nanofluid can be determined

as:

$$Pr_{nf} = \frac{\mu_{nf}c_{nf}}{k_{nf}} \quad (9)$$

The entire heat transfer coefficient can now be calculated as follows:

$$\frac{1}{UA} = \frac{1}{\eta_o h_a A_a} + \frac{1}{h_f A_f}$$

The Number of transfer units (NTU) of the nanofluid can be determined as:

$$NTU = \frac{UA}{C_{min}} = \frac{Q}{\Delta T C_{min}} \quad (10)$$

Q is average of heat transfer rate.

$$C_{min} = \min(C_c, C_h)$$

The heat exchanger effectiveness (ϵ) due to Leong *et al.* (2010) can be determined as:

$$\epsilon = 1 - \exp\left[\frac{NTU^{0.22}}{C^*} \exp(-C^* NTU^{0.78} - 1)\right] \quad (11)$$

Total heat transfer rate is given by

$$Q = \epsilon C_{min} [T_{Fluid (inlet)} - T_{air (inlet)}] \quad (12)$$

The power needed to pump coolant is provided by

$$P = V_f \Delta P \quad (13)$$

Where V_f is volumetric flow rate of fluid.

The performance index at this point can be defined as

$$P.I. = \frac{Q}{P} \quad (14)$$





RESULTS AND DISCUSSION

Graph (1) displays the size-dependent changes in effective thermal conductivity with nanolayer thickness for a variety of nanofluids. Our research shows that, of the nanofluids we examined, ZnO water (10 nm) has the highest effective thermal conductivity and TiO₂ water (10 nm) has the lowest. Graphs (2) and (3) show how the heat transfer coefficient varies as a function of the volume % of nanoparticles for a range of Reynolds and Prandtl values. As the Reynolds and Prandtl numbers rise, so does the heat transfer coefficient. Graphs (4) and (5) show the dependence of the Prandtl number on the volume fraction of nanoparticles for Al₂O₃ water (60.4 nm), Al₂O₃ ethylene glycol (26 nm), and TiO₂ water (10 nm), TiO₂ ethylene glycol (34 nm). Al₂O₃ ethylene glycol has a larger Prandtl number (26 nm) than Al₂O₃ water (60.4 nm), but TiO₂ ethylene glycol has a smaller Prandtl number (10 nm) than TiO₂ water (34 nm). Graph (6) shows how the Nusselt number of nanofluids changes as the volume percentage of nanoparticles changes for a range of Reynolds numbers. It has been discovered that as the Reynolds number rises, so does the Nusselt number of nanofluids. Graph (7) displays the relationship between the effective thermal conductivity and nanoparticle diameter for CuO water (18 nm) and CuO water (23.6 nm). CuO water (18 nm) is shown to have a higher effective thermal conductivity than CuO water (23.6 nm). The effective thermal conductivity of nanofluids is also found to decrease with increasing nanoparticle diameter. Graph (8) shows that as nanoparticle diameter grows, so does the volumetric ratio. TiO₂ water (34 nm) has a higher volumetric ratio than TiO₂ ethylene glycol (34 nm), as shown in the graph. The volumetric ratio of CuO water (23.6 nm) is greater than that of CuO water (18 nm) as shown in Graph 9. Graph (10) displays the relationship between heat transfer efficiency and NTUs for various nanofluid heat capacities. It has been found that a higher heat capacity ratio results in a more efficient heat exchanger. Graph (11) displays how the performance index varies with the volumetric flow rate of fluid for various heat capacity ratios of nanofluids. A higher heat capacity ratio is associated with a higher heat performance index.

Concluding Remarks

The thermal conductivity can be calculated using a mathematical model that was constructed. This model is a function of the thermal conductivities of both the fluid and the nanoparticle, as well as the nanolayer, volume fraction, and nanoparticle diameter. In light of the findings that were collected and validated, it has been determined that the thickness of the nanolayer that surrounds the nanoparticles as well as the Brownian motion play an essential part in the process of increasing the thermal conductivity of nanofluids. By solving the mathematical model with the help of the different assumptions, one can have a better understanding of the components that affect the overall improvement in thermal conductivity. It was discovered that the model that had been established could be used for virtually all of the nanofluids. The rise in the concentration of nanoparticles in nanofluids and the thickness of the nanolayers of nanofluids both contribute to an increase in the thermal conductivity of the nanofluids. When the diameter of the nanoparticles is increased, the thermal conductivity of the nanofluids experiences a drop. A potential line of inquiry for further research would be to investigate the causes that led to this result's limitations. Therefore, the application of this cutting-edge technology, which consists of suspending nanoparticles in base fluids, could offer solutions for better thermal management. An enhanced comprehension of complicated nanofluids will have an influence that is even more widespread.

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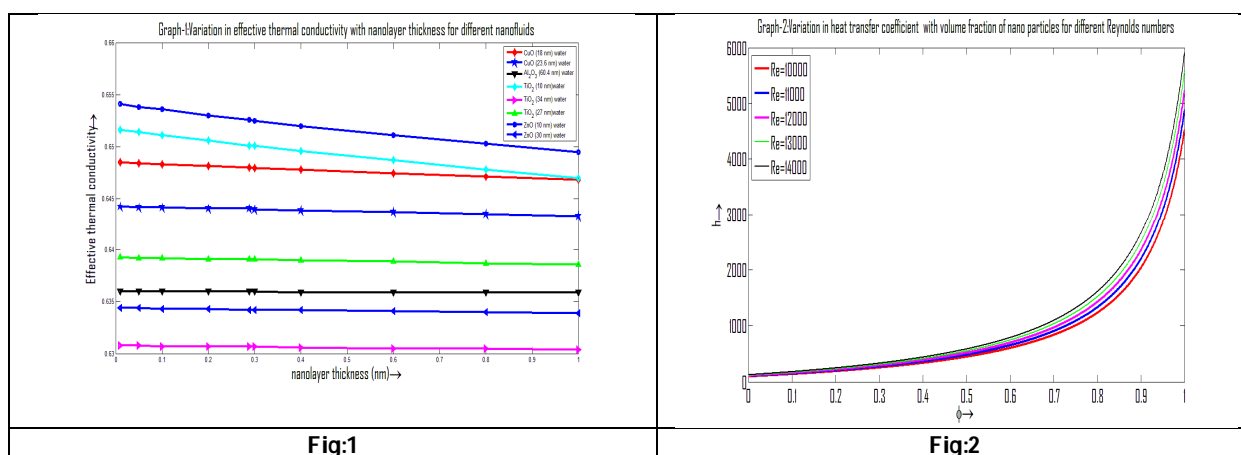
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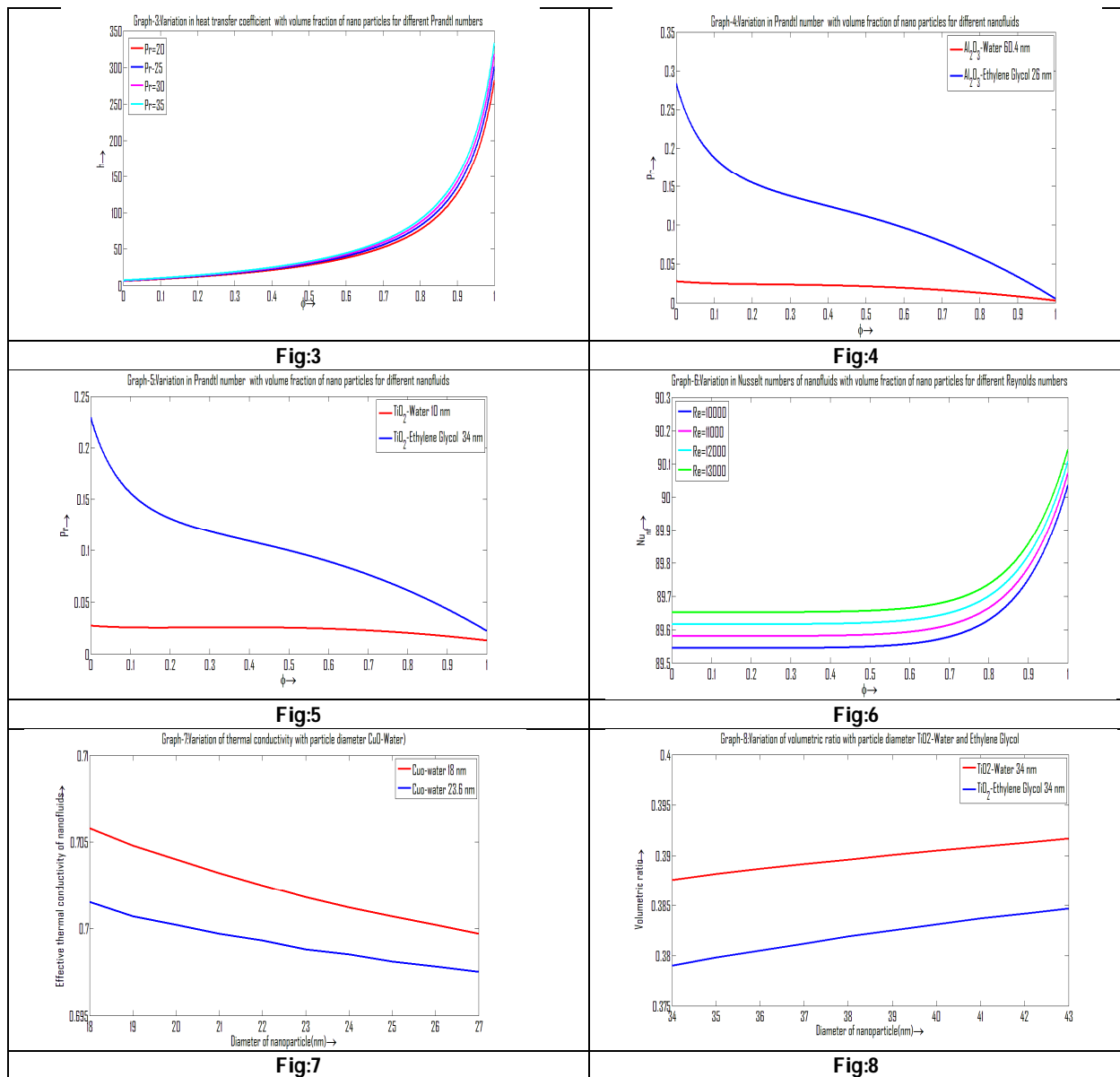




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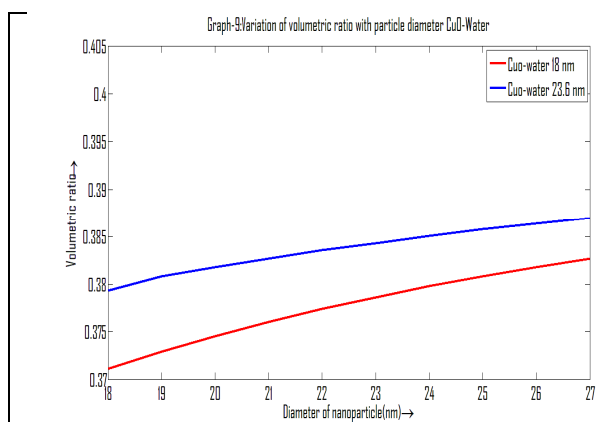


Fig:9

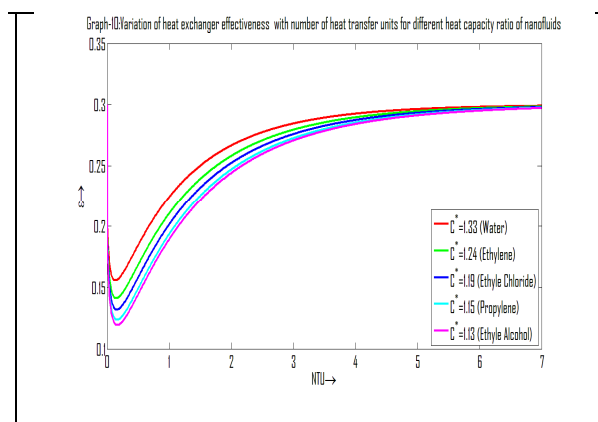


Fig:10

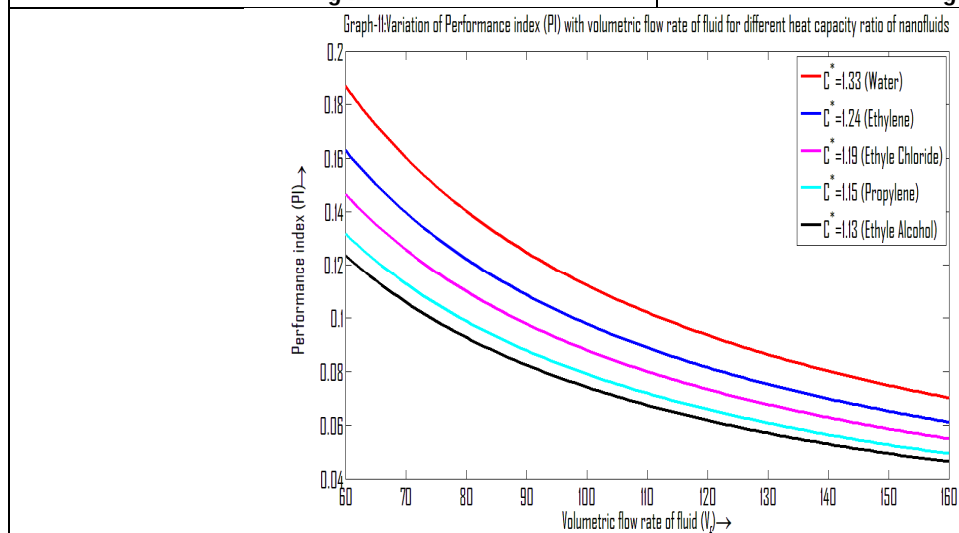


Fig:11





Multidimensional Benefits of Digitalisation in Organised Retail: Insights from Kerala's Diverse Ecosystem

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ABSTRACT

This study explores the multifaceted benefits of digitalisation in the organised retail sector of Kerala. It examines how digitalisation impacts organised retail businesses in Kerala, focusing on factors such as retail type, outlet age, employee numbers, and outlet size. Data were collected through questionnaires from 330 retail outlets in the Food & Grocery, Apparel, and Consumer Electronics sectors. Through an exploratory and confirmatory factor analysis, eight dimensions of digitalisation categorised into economic, technological, and social benefits were identified. Key findings reveal significant improvements in operational performance, market expansion, customer support, digital marketing strategies, and employment opportunities. While outlet age and sector showed no significant impact on digital benefits, larger outlets and those with more employees experienced greater advantages. These findings highlight the universal relevance of digitalisation in retail and the need for targeted strategies for smaller outlets.

Keywords: digitalisation, economic benefits, technological benefits, social benefits, outlet age, outlet size.

INTRODUCTION

Digitalisation has emerged as a pivotal force transforming the global retail landscape, enabling businesses to innovate, optimise operations, and enhance customer experiences (Grewal et al., 2020). It involves the integration of digital tools and technologies into various aspects of business operations, resulting in improved efficiency, cost reduction, and better customer engagement (Brynjolfsson & McAfee, 2014). The retail sector in India, which is among



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the fastest-growing in the world, has embraced digitalisation to keep pace with evolving consumer preferences and competitive pressures (Kumar & Gupta, 2021). The organised retail sector in Kerala provides a unique context to examine the impact of digitalisation due to its diverse retail ecosystem, ranging from large-format stores to technologically advanced retail chains. Retailers in Kerala have adopted digital technologies such as inventory management systems, digital marketing platforms, and cashless payment methods to enhance operational efficiency and cater to digitally savvy consumers (Raj & Abraham, 2019). Despite these advancements, there is limited empirical evidence on the multidimensional benefits of digitalisation within Kerala's retail sector. This study seeks to bridge this gap by categorising the benefits into economic, technological, and social domains and examining the variations across outlet characteristics. The findings are intended to provide actionable insights for retailers aiming to harness the full potential of digital transformation.

RESEARCH OBJECTIVES

1. To evaluate the economic, technological, and social benefits of digitalisation in retail operations.
2. To explore differences in digital benefits based on retail type, outlet age, employee numbers, and outlet size.

HYPOTHESES

Ho: There is no significant difference in the benefits of digitalisation among the different types of retail units.

H1: There is a significant difference in the benefits of digitalisation among the different types of retail units.

Ho: There is no significant difference in the benefits of digitalisation with respect to outlet age.

H1: There is a significant difference in the benefits of digitalisation with respect to outlet age.

Ho: There is no significant difference in the benefits of digitalisation with respect to employee numbers.

H1: There is a significant difference in the benefits of digitalisation with respect to employee numbers.

Ho: There is no significant difference in the benefits of digitalisation with respect to outlet size.

H1: There is a significant difference in the benefits of digitalisation with respect to outlet size.

RESEARCH PROBLEM

Despite the rapid adoption of digital technologies in the retail sector, there is limited empirical evidence on how these transformations impact organised retail businesses, particularly in Kerala. The extent to which digitalisation enhances operational performance, market share, customer engagement, and employment opportunities remains underexplored. Furthermore, the differential benefits experienced by retail outlets of varying sizes, types, and digital maturity levels necessitate a deeper investigation. Addressing this gap is crucial for guiding strategic decision-making and fostering sustainable growth in the sector.

MATERIALS AND METHODS

This study was designed as descriptive research, utilising both primary and secondary data. Primary data were collected from organised retail outlets in the Food & Grocery, Apparel, and Consumer Electronics sectors using pre-tested questionnaires. The questionnaire was distributed to 330 retail outlets (110 from each sector). A pilot study was conducted with 60 respondents to ensure reliability and validity. Reliability was ensured using Cronbach's alpha, normality was assessed through statistical tests, and validity was confirmed through expert reviews. A Likert scale was used to measure responses.

Sample Design

The population for this study comprises organised retail outlets in Kerala. A non-probability sampling technique was employed to select the sample respondents. The sampling process was conducted in the following stages:



**Ninikala****Stage 1: Selection of Cities**

Three major cities in Kerala with a high concentration of organised retail outlets were selected: Thiruvananthapuram, Ernakulam, and Kozhikode.

Stage 2: Selection of Retail Sectors

Three retail sectors were chosen based on their significant contribution to organised retail, as indicated by industry updates (Rating, 2019; IBEF, 2019). These sectors include Food & Grocery, Apparel, and Consumer Electronics.

Stage 3: Selection of Retail Outlets

Retail outlets from the identified sectors were selected using convenience sampling methods.

RESULTS AND DISCUSSIONS**DIMENSIONS OF DIGITALISATION BENEFITS**

From the exploratory factor analysis (EFA), eight dimensions of the benefits of digitalisation were identified, which were categorized into economic, technological, and social benefits. These dimensions are:

- **Economic Benefits:** Operational Performance, Increased Market Share
- **Technological Benefits:** New Market Opportunities, Inventory Management, Digital Marketing
- **Social Benefits:** Better Customer Support, Digital Payment, Employment Opportunities

Economic Benefits

- **Operational Performance:** Two key indicators were identified, with factor loadings of 0.776 and 0.663, indicating that digitalisation improves operational performance in retail outlets, surpassing traditional methods.
- **Increased Market Share:** Five indicators showed a significant influence on this dimension, with factor loadings ranging from 0.531 to 0.763. Digitalisation enables access to new markets, enhances customer awareness, allows for differentiation from competitors, provides better product information, and eases customer purchase processes.

Technological Benefits

- **New Market Opportunities:** Digitalisation helps identify new markets and expand businesses, with factor loadings of 0.666 and 0.602, respectively, highlighting the significance of digitalisation in business growth.
- **Inventory Management:** Three indicators were identified with factor loadings from 0.575 to 0.756, suggesting that digitalisation of inventory recording and management improves efficiency and stock level assessment.
- **Digital Marketing:** Six indicators revealed strong influences on digital marketing, with factor loadings from 0.452 to 0.864. Digital marketing platforms like social media have proven more cost-effective and better at targeting the desired audience compared to traditional marketing methods.

Social Benefits

- **Better Customer Support:** Digitalisation offers wide product/service variety, reduces prices, enhances customer service, and helps understand customer preferences. The factor loadings ranged from 0.556 to 0.938, underscoring digitalisation's pivotal role in improving customer relationships.
- **Digital Payment:** This dimension had five indicators with factor loadings from 0.358 to 0.896, demonstrating the significant role of digital payment methods (such as e-wallets and POS systems) in reducing cash handling risks and customer preference for digital transactions.
- **Employment Opportunities:** Four indicators revealed that digitalisation significantly influences employment, especially for technically qualified individuals, with the highest factor loading (0.958) for the role of social media marketing in creating jobs.



**Ninikala****CONFIRMATORY FACTOR ANALYSIS (CFA)**

CFA confirmed that all the models for the eight dimensions fit adequately, with significant regression coefficients across most indicators. The CFA results indicated that the most influential indicators were:

- **Operational Performance:** "Digitalisation improves the operational performance of the retail outlets" and "Operational performance of the traditional period was much better" had strong regression coefficients (0.803 and 0.853).
- **Increased Market Share:** All five indicators showed regression coefficients greater than 0.4, with the highest variance explained by the indicator "Digitalisation opens an avenue for customers to make purchases easier" (0.838).
- **New Market Opportunities:** Both indicators ("Digitalisation helps to identify new market opportunities" and "Digitalisation helps to expand businesses") had strong regression coefficients of 0.948 and 0.866.
- **Inventory Management:** Three indicators had significant regression coefficients, with "Recording of stock is fully digitalised" being the most influential (0.781).
- **Digital Marketing:** The indicator "Digital marketing reduces the cost of marketing" had the highest variance explained (88%).
- **Better Customer Support:** "Going digital has helped to better understand customer preferences" (0.938) was the most significant factor.
- **Digital Payment:** "Digitalisation reduces the risk in handling cash" had the strongest influence, with a regression coefficient of 0.896.
- **Employment Opportunities:** "Employment opportunities increased only for technically qualified persons" had the highest variance explained (91.8%).

COMPARISON OF THE BENEFITS OF DIGITALISATION ACROSS VARIOUS RETAIL SECTOR

The analysis shows that there is no significant difference in the benefits of digitalisation among the three retail sectors—Food & Grocery, Apparel, and Consumer Electronics as indicated by the acceptance of the null hypothesis (H_0) due to a p-value greater than 0.05. The mean values of benefits are very similar across these sectors: Food & Grocery (106.93), Apparel (106.25), and Consumer Electronics (107.20). This consistency highlights that digitalisation delivers uniform advantages across different retail categories. Key dimensions contributing to these benefits include improved operational performance, increased market share, new market opportunities, enhanced inventory management, effective digital marketing, better customer support, streamlined digital payments, and expanded employment opportunities. These findings suggest that digital strategies and tools are equally impactful across diverse retail units, enabling retailers to adopt similar digitisation initiatives and achieve comparable improvements. This universality also supports the formulation of broad-based digitalisation policies applicable to all retail sectors without requiring sector-specific differentiation.

DIGITALISATION BENEFITS AND OUTLET AGE

The analysis indicates no significant difference in the benefits of adopting digital methods based on the age of retail outlets, as the null hypothesis (H_0) was accepted due to a p-value greater than 0.05. The mean scores of digital benefits across different age groups of outlets are relatively close: outlets up to 10 years old scored 106.42, those between 11–20 years scored 109.74, outlets between 21–30 years scored 102.27, and those above 30 years scored 104.07. These results demonstrate that the advantages of digitalisation, such as improved operational performance, market share growth, better inventory management, and enhanced customer support, are consistent regardless of the outlet's age. The findings suggest that digital methods are universally effective across retail outlets, irrespective of their longevity, reinforcing the applicability of digital tools and strategies across both newer and more established retail businesses.

EMPLOYEE NUMBER AND THEIR EFFECT ON DIGITALISATION BENEFITS

The results of the one-way ANOVA indicate a significant difference in the benefits of adopting digital methods based on the number of employees in retail outlets, as evidenced by a p-value less than 0.05. Consequently, the null hypothesis (H_0) is rejected, and the alternate hypothesis (H_1) is accepted. The mean scores of digitalisation benefits



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increase with the number of employees: outlets with 100 or more employees have the highest mean score (124.45), followed by outlets with 50–100 employees (116.32), 25–50 employees (110), and less than 25 employees (102.7). A post hoc test further reveals that significant differences exist between most groups, except for the 25–50 and 50–100 employee categories, where the p-value is greater than 0.05. This suggests that larger outlets experience greater benefits from digitalisation compared to smaller outlets. The findings imply that the scale of operations, driven by the number of employees, amplifies the effectiveness of digital methods, potentially due to better resource utilization, more extensive digital adoption, and higher operational capabilities in larger outlets.

EFFECT OF OUTLET SIZE ON DIGITALISATION BENEFITS

The analysis indicates significant differences in the benefits of digitalisation across retail outlets of varying sizes, with larger outlets deriving greater advantages. Retail outlets of 20,000 square feet and above scored the highest (123.74), followed by outlets of 5,000–10,000 sq. ft. (122.67) and 10,000–20,000 sq. ft. (122.20), which showed similar benefit levels. Post hoc tests reveal that outlets less than 1,000 sq. ft. and 1,000–5,000 sq. ft. experience significantly fewer benefits compared to all other size groups, while outlets of 20,000 sq. ft. and above show significant differences only with the smallest outlets. These findings suggest that larger retail outlets can better leverage digitalisation, likely due to their capacity for advanced technological adoption and operational scalability, while smaller outlets may need targeted strategies to enhance digital benefits.

POLICY AND STRATEGIC IMPLICATIONS**Support for Smaller Outlets**

Develop targeted strategies to enable smaller outlets to leverage digital benefits effectively.

Inclusive Policy Frameworks

Formulate policies to promote uniform adoption of digital tools across sectors.

Enhancing Workforce Skills

Focus on training programs to equip employees with technical skills.

Resource Allocation

Encourage investments in scalable digital solutions for larger and mid-sized outlets.

CONCLUSION

The study demonstrates that digitalisation significantly enhances the operational and economic efficiency of retail outlets, fostering better market opportunities and customer relationships. While the benefits are uniform across retail types and outlet ages, larger outlets and those with more employees gain more advantages due to higher resource capacity and operational scalability. Smaller outlets, however, face challenges in leveraging these benefits effectively. Policymakers and stakeholders should focus on creating accessible digital solutions and providing support to smaller retailers to ensure equitable digital transformation across the sector.

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Table .1 KMO and Bartlett's Test - Benefits of Digitalisation

Variable	No. of Variables	Kaiser-Meyer-Olkin Measure of Sampling Adequacy	Bartlett's Test of Sphericity –Chi Square	df	Sig.
Boons of Digitalisation	32	0.842	11349.839	496	<0.001

Source: Primary Data

Table .2 Factors underlying Benefits of Digitalisation

Factor		Codes	Statements	Factor loading
Economic Benefits	Factor 1 Operational Performance	OP1	Digitalisation improves the operational performance of the retail outlets	0.776
		OP2	Operational performance of the traditional period was much better	0.663
	Factor 2 Increased Market Share	IMS1	Digitalisation enables the business to access new (geographical) markets	0.763
		IMS2	Digitalisation increases customer awareness of our product/services (broader customer access)	0.531
		IMS3	Digitalisation permits differentiating our products/services from those of our competitors.	0.619
		IMS4	Digitalisation provides customers with better information about our product/services.	0.696





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		IMS5	Digitalisation opens an avenue for customers to make his/her purchase easier.	0.712
Technological Benefits	Factor 3 New Market Opportunities	NMO1	Digitalisation helps to identify new market opportunities	0.666
		NMO2	Digitalisation helps to expand the business	0.602
	Factor 4 Inventory Management	IM1	Recording of stock is fully digitalised	0.717
		IM2	As the inventory management is fully digitalised it is easy to assess the stock level.	0.756
		IM3	Improves purchase efficiency	0.575
	Factor 5 Digital Marketing	DM1	Digital marketing is much better than traditional marketing	0.583
		DM2	Digital marketing reduces the cost of marketing	0.642
		DM3	Digital marketing allows you to target your needed audience.	0.606
		DM4	Most commonly used digital marketing platforms are social media	0.795
		DM5	TV ads are much better than social media ad	0.739
		DM6	We share the offers and discounts to the customers through WhatsApp/ Facebook/Instagram.	0.835
Social Benefits		BCS1	Digitalisation enables us to offer a wide variety of products/services to the customers.	0.777





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	Factor 6 Better Customer Support	BCS2	Digitalisation enables us to offer goods at reduced prices to the customers.	0.556
		BCS3	Digitalisation helps to provide better customer service	0.735
		BCS4	Going digital has helped to better understand the customer preference.	0.715
		BCS5	Digitalisation enables production of need oriented products/services.	0.601
	Factor 7 Digital Payment	DP1	We are accepting payment through POS machines.	0.484
		DP2	We prefer to make payment in cash	0.550
		DP3	We are accepting payment through e-wallet/UPI.	0.496
		DP4	Digitalisation reduced the risk of handling cash	0.571
		DP5	Digital mode of payment is preferred by the customer.	0.401
	Factor 8 Employment opportunities	EO1	Digitalisation led to increase in employment opportunities	0.803
		EO2	Employment opportunities increased only for technically qualified people.	0.720
		EO3	More employment opportunity raised in social media marketing	0.631
		EO4	Improved recruitment process	0.529
Source: Primary Data, Extraction method: Principal Component Analysis.				





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Table . 3 Reliability Statistics: Benefits of Digitalisation

Sl. No.	Constructs with its code name	Cronbach's Alpha	Number of Items	Code name given to the variables
A	Economic Boons			
1	Operational performance (OP)	0.812	2	OP1 & OP2
2	Increase in market share (IMS)	0.875	5	IMS1, IMS2, IMS3, IMS4 & IMS5
B	Technological Boons			
3	New market opportunities (NMO)	0.900	2	NMO1 & NMO2
4	Inventory management (IM)	0.842	3	IM1, IM2 & IM3
5	Digital Marketing (DM)	0.869	6	DM1, DM2, DM3, DM4, DM5 & DM6
C	Social Boons			
6	Better customer support (BCS)	0.898	5	BCS1, BCS2, BCS3, BCS4 & BCS5
7	Digital payment (DP)	0.807	5	DP1, DP2, DP3, DP4 & DP5
8	Employment Opportunities (EO)	0.723	4	EO1, EO2, EO3 & EO4

Source: Primary Data

Table .4 Model fit Indices for CFA- Benefits of digitalisation

	P	Normed χ^2	GFI	AGFI	NFI	TLI	CFI	RMR	RMSEA
Operational performance	.733	.116	1.000	.999	1.000	1.000	1.000	0	.073
Increase in market share	.169	1.896	.998	.966	.998	.991	.999	.008	.052
New market opportunities	.180	1.180	1.000	.960	1.000	.960	1.000	0	.057
Inventory management	.052	4.863	.931	.985	.985	.995	.984	.034	.071
Digital Marketing	.099	2.093	.994	.955	.995	.986	.997	.012	.058
Better customer support	.103	1.927	.991	.965	.994	.992	.997	.012	.053
Digital payment	.245	1.408	.997	.974	.988	.982	.996	.015	.035
Employment opportunities	.080	3.300	1.000	.910	1.000	.910	1.000	0	.035

Source: Primary Data

Table .5 The Regression Coefficients – Benefits of digitalisation

Factors	Construct	Regression Coefficient	C.R.	P	Variance explained (%)
Operational performance	OP1	0.803	20.018	<0.001	64.5
	OP2	0.853	22.913	<0.001	72.8
Increase in market share	IMS1	0.800	19.866	<0.001	64.0
	IMS2	0.723	16.526	<0.001	52.3
	IMS3	0.818	20.809	<0.001	66.9
	IMS4	0.771	18.495	<0.001	59.4
	IMS5	0.838	21.961	<0.001	70.2
New market opportunities	NMO1	0.948	32.760	<0.001	89.9
	NMO2	0.866	23.813	<0.001	75.0
Inventory management	IM1	0.781	18.950	<0.001	61.0
	IM2	0.760	18.015	<0.001	57.8
	IM3	0.552	11.234	<0.001	30.5
Digital Marketing	DM1	0.864	23.669	<0.001	74.6





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	DM2	0.938	31.124	<0.001	88.0
	DM3	0.757	17.887	<0.001	57.3
	DM4	0.645	13.864	<0.001	41.6
	DM5	0.484	9.551	<0.001	23.4
	DM6	0.452	8.810	<0.001	20.4
Better customer support	BCS1	0.800	19.866	<0.001	64.0
	BCS2	0.607	12.733	<0.001	36.8
	BCS3	0.713	16.153	<0.001	50.8
	BCS4	0.938	31.124	<0.001	88.0
	BCS5	0.876	24.562	<0.001	76.7
Digital payment	DP1	0.358	6.774	<0.001	12.8
	DP2	0.487	9.622	<0.001	23.7
	DP3	0.681	15.027	<0.001	46.4
	DP4	0.896	26.249	<0.001	80.3
	DP5	0.375	7.129	<0.001	14.1
Employment opportunities	EO1	0.204	3.741	<0.001	4.2
	EO2	0.958	34.738	<0.001	91.8
	EO3	0.716	16.264	<0.001	51.3
	EO4	0.14	7.964	<0.001	17.1
Source: Primary data					

Table .6 Benefits of Digitalisation and Type of Retail Unit

Variable	Type of retail unit	N	Mean	S.D.	F	p value
Benefits of digitalisation	Food & Grocery	110	106.93	15.48	0.088	0.916
	Apparel	110	106.25	18.96		
	Consumer Electronics	110	107.20	17.02		
Source: Primary Data						

Table .7 Benefits of Digitalisation and Outlet age

Variable	Outlet age	N	Mean	S.D.	F	p value
Benefits of adopting digital methods	Up to 10 years	184	106.42	17.55	1.955	0.121
	11-20 years	94	109.74	15.01		
	20-30 years	37	102.27	19.63		
	Above30 years	15	104.07	16.88		
Source: Primary Data						

Table .8 Benefits of Digitalisation and Number of Employees

Variable	Number of employees	N	Mean	S.D.	F	p value
Boons of Digitalisation	Less than 25	233	102.70	16.16	22.708	<0.001
	25-50	35	110.00	17.81		
	50-100	31	116.32	14.58		
	100 & above	31	124.45	9.03		
Source: Primary Data						





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Table .9 Multiple Comparison Tests- Benefits of Digitalisation and Number of Employees

Dependent Variable	Number of Employees		Mean Difference (I-J)	Std. Error	Sig.
Benefits of Digitalisation	Less than 25	25-50	-7.30472*	2.843	0.011
		50-100	-13.62730*	2.998	0.000
		100 & above	-21.75633*	2.998	0.000
	25-50	Less than 25	7.30472*	2.843	0.011
		50-100	-6.323	3.868	0.103
		100 & above	-14.45161*	3.868	0.000
	50-100	Less than 25	13.62730*	2.998	0.000
		25-50	6.323	3.868	0.103
		100 & above	-8.12903*	3.983	0.042
	100 & above	Less than 25	21.75633*	2.998	0.000
		25-50	14.45161*	3.868	0.000
		50-100	8.12903*	3.983	0.042

Table .10 Benefits of Digitalisation and Outlet size

Variable	Size of outlet	N	Mean	S.D.	F	p value
Benefits of Digitalisation	Less than 1000	114	94.83	14.20	42.068	<0.001
	1000-5000	155	109.26	14.95		
	5000-10000	27	122.67	12.20		
	10000-20000	15	122.20	9.62		
	20000 & above	19	123.74	9.12		
Source: Primary Data						

Table .11 Multiple Comparison Tests- Benefits of Digitalisation and Outlet size

Dependent Variable	Size of the Outlet		Mean Difference (I-J)	Std. Error	Sig.
Boons of Digitalisation	Less than 1000	1000-5000	-14.42473*	1.730	0.000
		5000-10000	-27.83333*	3.000	0.000
		10000-20000	-27.36667*	3.850	0.000
		20000 & above	-28.90351*	3.474	0.000
	1000-5000	Less than 1000	14.42473*	1.730	0.000
		5000-10000	-13.40860*	2.923	0.000
		10000-20000	-12.94194*	3.791	0.001
		20000 & above	-14.47878*	3.407	0.000
	5000-10000	Less than 1000	27.83333*	3.000	0.000
		1000-5000	13.40860*	2.923	0.000
		10000-20000	0.467	4.514	0.918
		20000 & above	-1.070	4.198	0.799
	10000-20000	Less than 1000	27.36667*	3.850	0.000
		1000-5000	12.94194*	3.791	0.001
		5000-10000	-0.467	4.514	0.918
		20000 & above	-1.537	4.842	0.751
	20000 & above	Less than 1000	28.90351*	3.474	0.000
		1000-5000	14.47878*	3.407	0.000
		5000-10000	1.070	4.198	0.799
		10000-20000	1.537	4.842	0.751





Decoding the Consumer Change to Herbal Products : An Analytical Approach

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ABSTRACT

Consumer preferences have changed in favour of herbal products in recent years, probably as a result of growing concerns about artificial substitutes and growing awareness of natural remedies. This study elucidates the characteristics that propel consumers toward herbal goods, highlighting the factors that impact their attitudes, preferences, and purchasing behaviour. A mixed-methods approach is used in this study including surveys and in-depth interviews to investigate consumer perceptions of herbal medicines' safety, efficacy, and environmental impact relative to conventional drugs. Key findings from the Factor Analysis (FA) technique indicate that despite concerns about product authenticity and regulatory constraints, people trust herbal remedies more because they perceive them to be natural with fewer side effects.

Keywords: Herbal products, Consumers, EDA, FA, Public health, Buying behaviour.

INTRODUCTION

In today's fast-paced society, characterized by rising stress, pollution, and sedentary lifestyles, the pursuit of comprehensive well-being has never been more pressing. A notable upsurge of interest in herbal items as natural therapies to support health, energy, and balance has occurred in this pursuit. For ages, herbal products—which are made from plant materials like roots, leaves, petals, and seeds—have been a crucial component of conventional medical practices. Not only in medical aspects, but also in their regular life routine wishes to take up herbal products as our ancestors practised regularly (Ex: Neem stick for brush). Herbal goods are becoming more and more popular



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as a result of a noticeable movement in consumer behaviour in recent years toward a healthier way of living. Due to their purported health benefits, herbal products—which are sourced from natural sources including plants, herbs, and botanical extracts—have become increasingly popular among consumers worldwide.

REVIEW OF LITERATURE

Gaining insight into how consumers view herbal goods is crucial for a range of stakeholders, including as researchers, marketers, legislators, and medical experts. It offers insightful information about the preferences, motives, and worries influencing customer behaviour in the market for herbal items. According to Kavita Sekhri et al. (2013), as herbal products are widely utilized to treat a variety of health issues, it is important to educate students about their use and improve their immunity level as well. People's need to be made aware of their potential drug interactions and safety issues. According to Kisan Shivaji Rao Desai's (2014) study, a number of factors have a big impact on what people decide to buy when it comes to herbal items in Kolhapur. The study improved consideration of consumer behaviour for cosmetic corporations by utilizing statistical methods and practical sampling. Consumer perception of Vindhya herbal products in Bhopal, India, is observed by Md. Irshad Ali et al. (2015), with a focus on awareness, usage, preferences, and attitudes toward herbal products. Only 23% of respondents to a bilingual study reported using Vindhya Herbal, but those who did liked it if it was accessible nearby. Because herbal goods are made of natural substances, most customers believe them to be safe and acts as immunity boosters. This product gets recommendations from media, relatives, and doctors. Mubarak (2020) examines the variables affecting Consumer Purchase Intention (CPI) for herbal items in Sri Lanka by utilizing information from 50 herbal outlets and 330 customers. The findings shows that while perceived risk has a negative effect, there is a significant positive correlation between CPI and perceived quality, value, price, and advertisement. Companies should concentrate on improving perceived quality, reducing risk using tactics like free samples, and using psychological pricing and brand endorsements to foster trust in order to increase CPI. In their investigation conducted in Malang, Indonesia, Rafadi Khan Khayru et al. (2021) discovered that decisions to buy herbal medicines are greatly influenced by all aspects of the marketing mix (product, pricing, promotion, and distribution), with the product having the most influence. Based on data gathered from 200 respondents, Sivaranjani S et al. (2023) investigate consumer perception and loyalty towards Himalaya products in Cuddalore District. It looks at how several aspects of Himalaya's product line pharmaceutical, personal care, baby care, wellness, and animal health affect consumer's opinions through percentage analysis. The results demonstrate the expanding market for herbal cosmetics as well as the possible influence of Himalayan product goods.

METHODOLOGY**DATA DESCRIPTION**

Primary data are used in this research. A questionnaire was generated specifically for the study, which involved college students and working professionals with ages ranging from 18 to 60 years. A convenience sampling approach is adopted to collect the 150 samples.

RESULTS AND DISCUSSION

Based on the responses received from the respondents, the data is using Exploratory Data Analysis (EDA) using descriptive measures to study some of the demographic variables such as age, income, gender and so on. Accordingly gives the Majority of the respondents are Female(64.7%) as well as Students(69.3%) belonging to the age group of 18-21(46.7%) years. Most of them (70.7%) use Herbal products in their day-to-day life because of the myth that there are no side effects (52.7%) and having a purchasing capacity in the range of Rs.500-1000(84.7%) on a monthly basis (69.3%). The respondents are being more health conscious (44.7%) so they mostly prefer natural/organic skincare products (49.3%) and medicinal products(26.7%) rather than Food products (24%). In order



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to assess the influencing factors in the study, one of the multivariate tests such as Factor Analysis(FA) is applied which is used for dimensionality reduction in data analysis. Its primary objective is identify patterns and structure in high-dimensional data by transforming it into a lower-dimensional space while preserving as much of the original information as possible. The Kaiser-Meyer-Olkin (KMO) test has been used to measure the relevance of the data for Principal Component Analysis(PCA). The test measures the sampling adequacy of each variable in the model ranging the value from 0 to 1. KMO test and Bartlett's sphericity test has been shown for adequacy checking of the data and results are presented in the table. **Table 2**, shows the KMO value as 0.876 indicating the value is highly adequate and satisfactory for Principal Component Analysis (PCA). From Bartlett's table sphericity, the associated probability is $0.000 < 0.05$ that means correlation matrix as identity matrix. The result from both the tests indicates that the data is fit for principal component analysis. **From Table 3**, it is clear that 60.988% of the original data has been retained into the components using principal component analysis. The 1st component value is $5.224 > 1$, 2nd component is $1.586 > 1$ and 3rd component is $1.119 > 1$. In this study, 13 variables are converted into three components known as factors and their inter-influence variables in the factor are studied using a rotated component matrix. **From Table 4** (Rotated component matrix), each number represents the partial correlation coefficient between variable and rotated component. These coefficients help in identifying the component. All the variables that have large factor loadings for a given component define the component. The factor analysis reveals three main factors influence on consumer's perceptions and decisions regarding herbal products.

Benefits of Herbal Products

Consumers value the superior quality(0.608), affordability(0.818), purity(0.776) and safety from natural ingredients(0.731). Herbal products are seen as offering a wide range of valuable options(0.662).

Rising Popularity and Availability

Herbal products are gaining popularity due to their natural benefits(0.776) and are frequently discussed(0.705). Their availability has expanded across various outlets(0.754), and advertising has become more prominent(0.796). They are also seen as competitive with global brands in terms of quality and price(0.501).

Essential Evaluation Factors

Consumers consider product source authenticity crucial(0.694) and associate lower prices with poor quality(0.784). Being well-informed before purchasing is important to ensure effectiveness and safety(0.545)

CONCLUSION

After analysing consumer perception towards herbal products, it is evident that these products hold a significant appeal among consumers. In recent times the herbal products market has undergone notable evolution. Most of the consumers use herbal products in their daily lives because there are no side effects. Many of them are being health conscious so they buy more skin care and medical products rather than food products. Recent trends in consumer perception towards herbal products reflect a growing interest in natural remedies, a focus on health and wellness, an emphasis on transparency and authenticity, considerations of environmental and ethical sustainability, the influence on digital platforms and advertisements and the diversification of product offerings. Brands that can effectively navigate these trends and meet evolving consumer expectations are poised to thrive in the dynamic landscape of the herbal products market.

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Table 1: DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

VARIABLES	NUMBER	PERCENTAGE (%)
GENDER		
Male	53	35.3
Female	97	64.7
AGE		
18-21	70	46.7
22-25	47	31.3
26-30	6	4
30-50	20	13.3
>50	7	4.7
OCCUPATION		





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Student	104	69.3
Employed	37	24.7
Unemployed	3	2
Others	6	4
USE OF HERBAL PRODUCTS IN DAY TO DAY LIFE		
Yes	106	70.7
No	44	29.3
PURCHASING BEHAVIOUR OF HERBAL PRODUCTS		
Daily	7	4.7
Weekly	15	10
Monthly	104	69.3
Never	24	16
AMOUNT SPEND FOR HERBAL PRODUCTS		
500-1000	127	84.7
1000-1500	15	10
1500-2000	4	2.7
>2000	4	2.7
PREFERENCE OF HERBAL PRODUCTS		
Medicinal products	40	26.7
Skincare products	74	49.3
Food products	36	24
REASON FOR PREFERRING HERBAL PRODUCTS		
No side effects	79	52.7
Health-conscious	67	44.7
Brand image	4	2.7

Table 2: KMO AND BARTLETT'S TEST

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.876
Bartlett's Test of Sphericity	Approx. Chi-Square	742.795
	Df	78
	Sig.	.000

Table 3: FACTOR ANALYSIS FOR EXPLAINING TOTAL VARIANCE

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.363	39.506	39.506	5.224	40.182	40.182	3.087	23.749	23.749
2	1.071	12.584	52.09	1.586	12.2	52.382	3.013	23.18	46.93





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3	0.775	9.103	61.193	1.119	8.607	60.988	1.828	14.058	60.988
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Table 4:ROTATED COMPONENT MATRIX

	Component		
	1	2	3
Herbal products are gaining popularity in the market		0.776	
Nowadays people often discuss about Herbal products		0.705	
Availability of Herbal products had increased in recent time.They are available everywhere from hari stores to hypermarkets		0.754	
Advertisement of herbal products are more visible in recent times		0.796	
Herbal products gained reputation because of superior quality and benefits	0.608		
Herbal products are easily affordable at better prices	0.818		
Herbal products symbolize purity	0.776		
Herbal products are safe because they are made from natural ingredients	0.731		
Herbal products offers a wide variety of products with better worth	0.662		
It is important to know the source of herbal products we use			0.694
Low prices are adjusted as poor quality.This perception will affect herbal products in future			0.784
Before purchasing any herbal products,we are sufficiently aware about the product			0.545
Herbal products compete with global brands in terms of affordability, quality and purity		0.501	





Shadow Education: A Theoretical Exploration of Private Tutoring and its Implications for Equity and Access in Global Education Systems

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ABSTRACT

Shadow education refers to private supplementary tutoring provided outside of regular school hours to support or enhance the academic performance of students. This phenomenon has become increasingly prevalent worldwide, powered by factors such as parental aspirations, highly competitive educational systems, and disparities in public education quality. This paper aims to explore the theoretical background of shadow education, exploring its historical context, key drivers, and educational theories that underpin its growth. Drawing on perspectives from human capital theory, social reproduction theory, education-for-all movement, and socio-cultural approaches, this paper will critically assess the implications of shadow education for equity, access, and quality in education. It concludes by highlighting the challenges and opportunities presented by shadow education in the broader educational context and offers potential strategies for addressing these issues within formal education systems.

Keywords: Challenges; Historical Context; Opportunities; Shadow Education; Quality Education

INTRODUCTION

Shadow education has emerged as a significant feature of contemporary education systems, particularly in societies where high-stakes examinations and meritocratic principles hold sway. The term "shadow education" is used metaphorically to describe its role as a parallel system to formal schooling. It mirrors the formal curriculum but operates outside the official structures, primarily in private and often informal settings. This system is especially prevalent in contexts where academic achievement is closely tied to future socioeconomic opportunities, such as in



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East Asia, Europe, and North America (Byun & Park, 2012; Bray, 2017; Bray, 2023). Shadow education encompasses various forms of supplementary tutoring, test preparation, and academic coaching aimed at enhancing students' performance in formal education settings (Zhang & Bray, 2015; Alam & Zhu, 2022). Its rapid growth across the globe has sparked increasing academic interest, particularly regarding its theoretical underpinnings, its relationship with mainstream schooling, and its effects on societal inequalities. Historically, shadow education has been perceived as a supplementary resource for those seeking academic advantages in highly competitive academic environments (Davies & Aurini, 2006; Zhang & Bray, 2015; Bae & Choi, 2023). The rise of shadow education can be traced back to the growing demand for academic success, driven by the belief that educational attainment serves as a primary means of social mobility. In many countries, shadow education plays a pivotal role in helping students prepare for entrance examinations, often regarded as gateways to prestigious universities and lucrative careers (Zhang & Bray, 2016; Jung, 2018; Jansen et al., 2023). The expansion of shadow education, therefore, raises critical questions about its influence on the formal education system and the extent to which it reinforces or reduces educational inequities.

From a sociological perspective, shadow education can be understood as part of the broader phenomenon of educational stratification. Bourdieu's (1986) theory of cultural capital is particularly relevant, as it suggests that families with greater financial resources are more likely to invest in supplementary education for their children. This investment in shadow education can increase their children's academic success and, by extension, their social standing (Tsiplakides, 2018; Gupta, 2023). In this way, shadow education perpetuates existing social hierarchies, allowing those from more affluent backgrounds to maintain their privileged status (Stevenson & Baker, 1992). Thus, one of the central critiques of shadow education is its role in increasing educational inequality by providing additional advantages to students from wealthier families while leaving disadvantaged students behind.

Economic theories also contribute to understanding the growth of shadow education, particularly through the lens of supply and demand. In regions where formal education systems are perceived as insufficient in preparing students for high-stakes exams, the demand for supplementary tutoring increases (Bray & Kwo, 2013; Gupta, 2021a; Alam & Zhu, 2022). As a result, the shadow education market thrives, with private tutoring companies and individual tutors responding to this demand. This market-driven nature of shadow education can lead to a widening gap between students who can afford these services and those who cannot, thus perpetuating inequities in educational outcomes. Educational perspectives on shadow education often focus on its pedagogical implications (Gupta & Zhang, 2023). Proponents argue that shadow education can provide personalized learning experiences, allowing students to receive tailored instruction that meets their individual needs (Jones & Rhein, 2017; Entrich, 2020; Liu, 2023). This is particularly valuable in contexts where formal classrooms are overcrowded, and teachers may not have the capacity to offer personalized attention to each student (Ball, 2018; Yang et al., 2023). However, critics point out that the commodification of education through shadow tutoring shifts the focus away from holistic educational development to narrowly defined academic success, often measured by test scores. This emphasis on rote learning and exam preparation can undermine the broader goals of education, such as fostering critical thinking and creativity. The rapid expansion of shadow education raises broader questions about educational equity, access, and outcomes. On one hand, shadow education may provide students with additional opportunities to succeed academically, particularly in systems where formal education is inadequate (Dang & Rogers, 2008; Li, 2020; Gupta, 2021b). On the other hand, its growth reflects deeper societal inequalities, as access to quality shadow education is often limited to those who can afford it. This dual nature of shadow education as both an opportunity and a barrier complicates its role within the broader education system. By situating shadow education within sociological, economic, and educational paradigms, it becomes clear that its expansion is driven by complex factors, including societal pressures for academic success, economic incentives, and gaps in formal education systems. As shadow education continues to evolve, it is essential to critically examine its implications for educational equity and access. Understanding the forces driving the growth of shadow education can inform policies aimed at addressing its impact on the broader education system, particularly in terms of reducing inequalities and ensuring that all students have the opportunity to succeed academically.





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Significance of the Study

Shadow education has become a prominent feature in contemporary educational contexts globally (Bae & Choi, 2023). This study is significant for several reasons, particularly in understanding the multifaceted impact of shadow education on educational equity, access, and quality. As an increasingly widespread phenomenon, shadow education reflects broader societal trends and educational policies that warrant comprehensive examination. First, this study contributes to the literature by providing a thorough theoretical background on shadow education. By exploring the historical context and key drivers behind its rise, the study sheds light on how parental aspirations, competitive educational systems, and disparities in public education quality contribute to the rapid increase of private tutoring (Bray & Kwo, 2013; Jung, 2018; Li, 2020; Entrich, 2020; Gupta, 2021b; Bray, 2023;). This understanding is crucial for educators, policymakers, and researchers who seek to grasp the underlying factors influencing the growth of shadow education and its implications. Second, the study employs various educational theories to critically assess shadow education's implications. Drawing on human capital theory, the research examines how shadow education impacts students' academic performance and future opportunities (Burgess, 2016; Wang & Liu, 2016; Tan & Liu, 2023). By incorporating social reproduction theory, it explores how shadow education can perpetuate social inequalities, reinforcing existing educational disparities (Bourdieu, 1986). Additionally, the study considers the education-for-all movement and socio-cultural approaches to evaluate shadow education's role in promoting or hindering equitable access to educational resources (Colclough et al., 2005; Vygotsky, 1978). This theoretical framework provides a depth analysis of the benefits and challenges associated with shadow education. Moreover, the study addresses the implications of shadow education for equity and access within educational systems. As shadow education often caters to students from higher socio-economic backgrounds, it can exacerbate existing inequalities in access to quality education (Da Wan & Weerasena, 2017; Jokila et al., 2020; Chimbunde & Jakachira, 2024). Understanding these dynamics is vital for developing strategies to mitigate the negative effects of shadow education and enhance equity within formal education systems. Finally, the study identifies challenges and opportunities presented by shadow education, offering practical recommendations for policymakers and educators. By exploring potential strategies for integrating shadow education insights into formal education systems, the research aims to contribute to more equitable and effective educational practices. This has significant implications for improving educational quality and ensuring that all students have access to the support they need to succeed academically. In summary, this study's significance lies in its comprehensive examination of shadow education's theoretical underpinnings and practical implications, providing valuable insights for advancing educational equity and quality in a competitive and evolving educational environment.

Objectives

The primary objectives of this research are as follows:

- To examine the historical development and growth of shadow education globally.
- To explore the educational theories that underpin the rise of shadow education
- To analyze the impact of shadow education on educational equity and access
- To critically assess the implications of shadow education for policy interventions.
- To provide potential strategies for strengthening formal schooling to reduce the proliferation of shadow education

Historical Context of Shadow Education

Shadow education is a phenomenon that has existed for centuries, although its scale and form have evolved considerably over time (Bray, 2017). The concept of additional, informal instruction outside of mainstream schooling is not a new development. Historically, such practices were prevalent, particularly among the elite classes, who sought to provide their children with a competitive edge in education. For instance, in ancient Greece and Rome, private tutoring was a common practice among wealthy families. These families employed personal tutors to educate their children in a wide array of subjects, including philosophy, rhetoric, and mathematics, well beyond the basic education provided by public schools of the time (Holloway & Kirby, 2019; Zwier et al., 2021; Bray & Lykins, 2012). Similarly, in early China, the tradition of private tutoring dates back to the imperial examination system, which was established as a means of selecting government officials based on merit (Tan & Liu, 2023; Xiang et al., 2023). The



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exams were notoriously competitive, and success in them offered a prestigious path to socioeconomic advancement. Consequently, families with sufficient financial resources often hired private tutors to help their children prepare for these exams, ensuring they had the best possible chance of securing a government position (Zhang & Bray, 2016; Jung, 2018; Jansen et al., 2023). This early form of shadow education, rooted in the need to excel in rigorous academic assessments, bears a resemblance to modern-day practices (Bray & Lykins, 2012; Zwier et al., 2021). The modern expansion of shadow education can be traced to several key factors. One significant driver has been the growing importance of formal education in contemporary societies. As education became increasingly recognized as a key determinant of social and economic mobility, the demand for additional educational support increased (Bray, 2017; Bray, 2023). In many countries, the focus on competitive standardized testing further powered the growth of private tutoring (Davies & Aurini, 2006; Zhang & Bray, 2015; Bae & Choi, 2023). High-stakes exams, particularly those determining university entrance or professional qualifications, created a culture of academic pressure, where students and their families sought every possible advantage to ensure success (Dang & Rogers, 2008; Li, 2020; Gupta, 2021b). In the late 20th century, East Asian countries such as Japan, South Korea, and Singapore witnessed an unprecedented rise in the shadow education sector. These countries developed highly competitive educational systems, where academic achievement was closely tied to future career prospects and social status.

As a result, private tutoring became deeply entrenched in these societies. In South Korea, for example, the intense competition surrounding the national college entrance exam led to the widespread reliance on private cram schools, or "hagwons," where students spent long hours in supplementary classes designed to boost their exam scores (Dang & Rogers, 2008; Piao & Hwang, 2021; Byun et al., 2023; Bae & Choi, 2023). Similarly, in Japan, the practice of attending "juku," or private tutoring schools, became a norm for students aiming to secure spots in prestigious high schools and universities (Mawer, 2015; Yamato et al., 2017; Kato & Kobakhidze, 2024). While the phenomenon of shadow education initially took root in East Asia, it has since spread across the globe, becoming a prominent feature of education systems in many countries (Bray, 2023). In North America and Europe, private tutoring has gained popularity as parents and students seek to move through increasingly competitive academic environments (Byun & Park, 2012; Bray, 2017). The expansion of private tutoring services in these regions has been driven by a variety of factors, including concerns about public school quality, the rise of standardized testing, and a growing belief in the importance of individualized, personalized learning (Jones & Rhein, 2017; Entrich, 2020; Liu, 2023). Africa, too, has witnessed the expansion of shadow education, although the drivers differ slightly from those in other regions. In many African countries, the demand for private tutoring has been linked to overcrowded and underfunded public education systems (Mlawwa & Mtitu, 2022; Hajar & Karakus, 2022). As a result, families that can afford it often turn to private tutors to supplement their children's learning and compensate for gaps in the formal education system. Additionally, as globalization has emphasized the importance of academic credentials in the job market, African students and their families increasingly view private tutoring as a necessary investment in future success (Dang & Rogers, 2008; Li, 2020; Liu, 2023). In sum, shadow education has a long history that stretches across different cultures and time periods. While its forms and functions have evolved, its core purpose remains the same: to provide students with additional educational resources outside of mainstream schooling to gain a competitive edge. Today, shadow education is a global phenomenon, influenced by a wide range of socioeconomic, cultural, and educational factors (Bray, 2017; Tsiplakides, 2018; Entrich & Lauterbach, 2020). Whether driven by the pressure of high-stakes exams, the desire for upward social mobility, or the need to compensate for deficiencies in formal education systems, shadow education continues to play a significant role in shaping the educational context worldwide (Dang & Rogers, 2008; Bray & Lykins, 2012; Gupta, 2021a; Alam & Zhu, 2022; Bae & Choi, 2023).

Theoretical Foundations of Shadow Education

Understanding the theoretical background of shadow education requires a multidisciplinary approach that integrates insights from economics, sociology, and educational theory. Several key theoretical frameworks help explain the rise and persistence of shadow education:

- **Human Capital Theory:** Human capital theory is one of the foundational economic perspectives used to explain the growth of shadow education. This theory, developed by economists such as Gary Becker, posits that





individuals and societies invest in education to enhance productivity and future earning potential (Becker, 1964; Becker, 1993). Shadow education, from this perspective, represents an additional investment in human capital, as families seek to improve their children's academic performance and, by extension, their future job prospects. In highly competitive educational systems, where academic success is closely linked to socioeconomic outcomes, shadow education becomes a strategic tool for families to maximize their children's chances of success (Burgess, 2016; Wang & Liu, 2016; Tan & Liu, 2023). This is particularly evident in countries like South Korea, where the societal emphasis on educational achievement drives a thriving private tutoring industry (Park *et al.*, 2011; Zhang, 2023). Human capital theory thus helps explain the rationale behind the increasing demand for shadow education, especially in contexts where formal schooling is perceived as insufficient for achieving academic success.

- **Social Reproduction Theory:** Another critical framework is Pierre Bourdieu's reproduction theory, which emphasizes how education systems perpetuate social inequalities. Bourdieu & Passeron (1990) argued that educational success is strongly influenced by cultural capital, which includes the knowledge, attitudes, and language skills passed down from parents to their children. Shadow education can be seen as a way for privileged families to further accumulate and transmit cultural capital to their children, reinforcing social hierarchies (Javadi & Kazemirad, 2020; Lee *et al.*, 2023). Wealthier families, who can afford private tutoring, are more likely to ensure their children's success in education, thus maintaining their privileged status (Tan & Yang, 2019; Bai, 2021; Wang & Wang, 2021). Shadow education, therefore, functions as a mechanism for the reproduction of social class distinctions, as it disproportionately benefits students from higher socio-economic backgrounds (Enrich & Lauterbach, 2020; Agrawal *et al.*, 2024)
- **Educational Stratification Theory:** Educational stratification theory addresses the ways in which educational systems contribute to social stratification. Shadow education can increase existing inequalities in education by creating a parallel system that benefits those who can afford to participate (Stevenson & Baker, 1992). As students from wealthier families are more likely to access high-quality private tutoring, they are also more likely to achieve higher academic outcomes, reinforcing the cycle of inequality. The expansion of shadow education can also lead to greater stratification within the formal education system, as students who receive private tutoring outperform their peers in standardized assessments, college entrance exams, and other educational benchmarks (Bray, 2017; Alam & Zhu, 2022; Jansen *et al.*, 2023). This creates a tiered educational system, where access to quality education becomes increasingly dependent on financial resources.
- **Socio-Cultural Approaches:** Socio-cultural theories, drawing on the work of Vygotsky (1978) and others, emphasize the role of social and cultural factors in shaping educational experiences. From this perspective, shadow education can be understood as a response to the cultural expectations and social norms that govern educational achievement. In societies where academic success is highly valued, families may feel compelled to invest in supplementary tutoring to meet societal expectations. In countries like Japan and China, where "exam culture" is deeply ingrained, shadow education is viewed as a necessary step for students to excel in highly competitive environments (Yamato *et al.*, 2017; Gupta 2021a; Alam & Zhu, 2022). Socio-cultural theories also highlight the role of parental involvement in shadow education, as parents actively seek out tutoring services to support their children's academic growth. This aligns with the notion of "concerted cultivation" proposed by sociologist Annette Lareau, where middle-class parents engage in intensive efforts to provide their children with educational advantages (Lareau, 2011).

Education for All and Equity Perspectives

The global movement for Education for All (EFA), initiated by UNESCO in the early 1990s, sought to promote access to quality education for all children, regardless of socioeconomic background. However, the rise of shadow education has raised concerns about its impact on educational equity. While shadow education can enhance the academic performance of students who have access to it, it can also increase existing inequalities by privileging those who can afford private tutoring (Bray, 2010; Jokila *et al.*, 2020; Chimunde & Jakachira, 2024). The EFA framework emphasizes the importance of providing equal opportunities for all students to succeed in formal education. Shadow education, however, creates a parallel system where students from wealthier backgrounds have access to additional



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resources, while those from lower-income families may be left behind (Tang & Yang, 2019; Bai, 2021; Wang & Wang, 2021). This raises critical questions about the role of shadow education in perpetuating or reducing educational inequalities.

Shadow Education and Educational Equity

The debate surrounding the impact of shadow education on educational equity is complex and multifaceted. On one side, proponents argue that shadow education offers students additional academic support, enhancing their performance in areas where they might struggle within the traditional schooling system. These supplementary educational services, such as private tutoring and test preparation, can help students gain a competitive edge, especially in high-stakes subjects (Davies & Aurini, 2006; Alam & Zhu, 2022; Bae & Choi, 2023). By providing more individualized attention and tailored instruction, shadow education has the potential to address learning gaps that may not be adequately covered in formal education, particularly for students with varying learning needs or those who require extra assistance to keep up with their peers. However, critics argue that shadow education contributes to deepening educational inequalities. They suggest that students from wealthier families, who can afford private tutoring, are disproportionately advantaged, leaving behind their less affluent peers who may lack the financial resources to access such services (Jolila et al., 2020; Agrawal et al., 2024; Chimunde & Jakachira, 2024). This creates a dual-track system, where educational success becomes increasingly dependent on a family's ability to invest in supplementary education, thus reinforcing socioeconomic disparities. The exclusive nature of shadow education can result in unequal opportunities for academic advancement, as wealthier students benefit from the additional resources and instruction that enable them to excel, while disadvantaged students may fall further behind (Tan & Yang, 2019; Bai, 2021; Wang & Wang, 2021). Empirical research reveals that the effects of shadow education on educational equity are both positive and negative. On the one hand, it can provide a valuable opportunity for students to receive personalized instruction, which can be especially beneficial for those struggling in the mainstream system (Jones & Rhein, 2017; Entrich, 2020; Liu, 2023). Yet, this benefit often comes at a cost, as the financial barrier limits access to only a privileged few. As a result, shadow education can simultaneously serve as a tool for academic improvement while also perpetuating the very inequalities it seeks to address. Thus, while shadow education can offer short-term gains for individual students, its broader societal implications raise concerns about its role in widening the equity gap in education systems worldwide. In conclusion, while shadow education holds promise as a means to address specific learning challenges, it also poses significant risks to educational equity, disproportionately favoring those with financial means (Davies & Aurini, 2006; Alam & Zhu, 2022; Bae & Choi, 2023).

Policy Implications and Challenges

The emergence and growth of shadow education, or private supplementary tutoring, present significant challenges for both policymakers and educators. One major issue is the potential for shadow education to undermine the objectives of formal schooling by reallocating resources and focus from public education systems. For instance, in countries like South Korea and Japan, where shadow education is highly prevalent, governments have introduced various policies aimed at regulating the private tutoring industry to alleviate the pressures on students and their families (Mawer, 2015; Yamato et al., 2017; Byun et al., 2023; Kato & Kobakhidze, 2024). These policies often include measures such as limiting the hours of private tutoring or setting standards for tutoring institutions. However, the effectiveness of such regulations can be mixed and dependent on how they are implemented and enforced. In addition to resource diversion, shadow education increases issues of educational equity. Access to high-quality private tutoring is often correlated with socio-economic status, leading to disparities in educational opportunities among students (Jokila et al., 2020). Wealthier families can afford extensive supplementary education, which can give their children a competitive edge, while those from less affluent backgrounds may not have the same opportunities (Wang & Wang, 2021). This disparity raises critical concerns about fairness in educational outcomes and the perpetuation of existing inequalities. Policymakers face the challenge of addressing these equity issues by ensuring that all students have equal access to quality education, irrespective of their financial capabilities. To address these challenges, a multifaceted approach is necessary. One strategy involves enhancing the quality of public education systems to reduce the perceived need for supplementary tutoring. This could include investing in teacher training, curriculum development, and educational resources to improve overall teaching and learning experiences within the



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formal school system (Park et al., 2011; Gupta & Zhang, 2023). Additionally, reducing the emphasis on high-stakes examinations, which often drive the demand for shadow education, can help reduce the pressure on students and families. High-stakes tests can incentivize excessive reliance on private tutoring, as families may feel compelled to seek additional academic support to achieve favorable results. Furthermore, providing targeted support for disadvantaged students within the public education system can help bridge the gap created by the availability of shadow education. This support might involve offering free or subsidized tutoring services, implementing after-school programs, and providing additional resources to schools serving lower-income communities. By addressing the needs of students who are most at risk of falling behind, policymakers can help level the playing field and reduce the reliance on private tutoring. Overall, while shadow education presents complex challenges, there are several strategies that policymakers and educators can employ to address these issues. By focusing on improving public education quality, reforming assessment practices, and supporting disadvantaged students, it is possible to create a more equitable educational landscape and mitigate the negative effects of shadow education.

Potential Strategies for Strengthening Formal Schooling to Reduce the Proliferation of Shadow Education

The shadow education phenomenon reflects growing concerns about the adequacy of formal education systems to meet diverse learning needs and the increasing demand for additional academic support. To address these concerns, it is essential to explore and implement strategies that can strengthen formal schooling and reduce reliance on shadow education. The investigators have delineated some approaches that can enhance the quality of formal education and thus reduce the need for supplementary tutoring.

Strategies for Strengthening Formal Schooling

- **Curriculum Enhancement and Relevance:** A key strategy for reducing the need for shadow education is to enhance the relevance and quality of the formal curriculum. This involves ensuring that the curriculum is comprehensive, up-to-date, and aligned with students' developmental needs and future opportunities. By integrating critical thinking, problem-solving, and real-world applications into the curriculum, schools can better prepare students for academic and life challenges (Yoo, 2024). Additionally, a well-designed curriculum should accommodate diverse learning styles and needs, reducing the reliance on external tutoring for academic support.
- **Professional Development for Educators:** Teachers play a crucial role in shaping the educational experience. Investing in continuous professional development for educators is essential for improving teaching quality and effectiveness. Training programs should focus on modern pedagogical techniques, classroom management strategies, and differentiated instruction to cater to varied learning needs. By enhancing teachers' skills and knowledge, schools can provide more effective instruction and support, thereby decreasing the need for shadow education.
- **Assessment and Feedback Mechanisms:** Implementing robust assessment and feedback mechanisms within formal education can address learning gaps and provide timely interventions. Formative assessments, regular feedback, and progress monitoring help educators identify students' strengths and weaknesses early on. By using this data to tailor instruction and provide targeted support, schools can reduce the need for additional tutoring services. Furthermore, transparent and fair assessment practices can reduce the pressure associated with high-stakes testing, which often drives students and parents toward shadow education.
- **Parental Involvement and Support:** Engaging parents in the educational process is another effective strategy for strengthening formal schooling. Schools can foster strong partnerships with parents through regular communication, parent-teacher meetings, and involvement in school activities. Providing parents with resources and guidance on how to support their children's learning at home can reduce their reliance on external tutoring services (Park et al., 2011). By creating a supportive learning environment both at school and at home, students are more likely to thrive without the need for additional shadow education.
- **School Resources and Infrastructure:** Adequate resources and infrastructure are vital for delivering high-quality education. Schools should be equipped with up-to-date learning materials, technology, and facilities that support interactive and engaging instruction. Investing in resources such as digital tools, library materials, and extracurricular programs can enhance the overall educational experience and reduce the need for



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supplementary tutoring (Tomar, 2012). Additionally, ensuring equitable access to resources across different schools and communities helps address disparities that contribute to the proliferation of shadow education.

- **Effective Teaching Practices:** Professional development programs for teachers should focus on modern instructional techniques that foster active learning, student engagement, and individualized instruction. Teachers who are well-trained in innovative pedagogical strategies can better address students' needs within the classroom, reducing the perceived necessity for additional tutoring (Entrich, 2020; Liu, 2023).
- **Promoting Equity and Accessibility:** Ensuring that all students have access to high-quality education is essential in reducing reliance on shadow education. This involves addressing disparities related to socioeconomic status, geographical location, and other factors that can affect educational opportunities. Policies that promote equitable funding for schools, targeted support for disadvantaged students, and community involvement in education can help level the playing field (Jokila et al., 2020).
- **Policy and Systemic Reforms:** Finally, systemic reforms at the policy level can address the root causes of shadow education. Governments and educational authorities should focus on creating policies that promote educational equity, reduce testing pressure, and support comprehensive school reforms (Xiang et al., 2023). Implementing measures such as adjusting standardized testing practices, increasing funding for public schools, and promoting inclusive education can help create a more equitable and effective educational system. By addressing systemic issues, policymakers can reduce the reliance on shadow education and improve the overall quality of formal schooling.

CONCLUSION

Shadow education is a multifaceted and intricate phenomenon that mirrors broader societal trends concerning education, socioeconomic mobility, and cultural expectations. This form of supplementary education, often provided through private tutoring or after-school programs, has become increasingly prevalent worldwide. On one hand, shadow education can offer significant support to students by enhancing their learning experiences and academic performance. It provides additional resources and personalized attention that may not always be available in formal educational settings. However, the rise of shadow education also brings to light pressing issues related to educational equity and access. The growing reliance on such supplementary programs can increase existing disparities, as students from more affluent families are more likely to benefit from these additional resources compared to their less privileged peers. The expanding reach of shadow education necessitates a critical evaluation of its effects on formal education systems. Policymakers and educators must carefully consider how these supplementary programs impact overall educational equity and the effectiveness of traditional schooling. Strategies need to be developed to address the challenges posed by shadow education, ensuring that it does not perpetuate or worsen existing inequalities. This includes examining how shadow education influences educational outcomes and whether it contributes to an environment where success is increasingly dependent on the ability to access supplementary support. As shadow education continues to evolve and grow, it is crucial for stakeholders in the education sector to remain vigilant. Understanding the complex dynamics of shadow education will help in crafting policies that promote a more equitable educational landscape. By addressing the challenges associated with shadow education, policymakers and educators can work towards creating a more inclusive and fair system that supports all students, regardless of their socioeconomic background.

Further Research

Further research on shadow education could build upon its historical context and key drivers by examining how these factors interact with evolving educational policies and technological advancements. One avenue for exploration is the impact of digital tools and online platforms on the proliferation of shadow education, considering how they might increase or decrease existing disparities. Additionally, investigating the role of shadow education in different cultural and socioeconomic contexts could provide a more depth understanding of its implications for educational equity. Comparative studies across various countries could reveal how different educational systems respond to and manage shadow education. Another important area of research could involve evaluating the effectiveness of





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interventions aimed at reducing reliance on shadow education, such as reforms in public schooling and alternative support mechanisms. This approach could help in formulating evidence-based strategies to balance the benefits and drawbacks of shadow education, ensuring that its advantages in enhancing academic performance do not perpetuate existing inequities. Overall, a comprehensive analysis of these dimensions will contribute to a more robust understanding of shadow education's role in contemporary education and its potential for shaping future educational practices.

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Fig :2 The symbolic illustration representing the theoretical foundations of shadow education, incorporating elements of Human Capital Theory, Social Reproduction Theory, Educational Stratification Theory, and Socio-Cultural Approaches.





Fig :3 An illustration that contrasts Shadow Education and Educational Equity. It visually depicts the Disparities and emphasizes the importance of Equitable Education Systems.



Fig:4 An illustration showcasing strategies for strengthening formal schooling. It depicts a modern, inclusive, and engaging classroom environment with interactive teaching, technology integration, and collaborative learning activities.





Standardization of Vaazhai Pazha Jayaneer and Evaluation of its Anti-Bacterial Property against Urinary Tract Infection (*Neerchurukku*) Causing Pathogens

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ABSTRACT

Minerals, metallic preparations and medicinal plants used in Siddha Medicine are outstanding in their therapeutic value. *Jayaneer* is a pungent liquid prepared by exposing to night dew a mixture of powdered lime and ammoniac. It is supposed to be a solvent medium for many insoluble substances and as such is used for preparing medicines of very high potency. This *Jayaneer* is a medicinal preparation of pungent liquid obtained by what night' dew on a porcelain dish containing a mixture of *Rasthaali* Banana, Limestone and Ashes of banana bark. Generate SOP for the preparation of the *Vaazhai Pazha Jayaneer* Standardization as per PLIM guidelines and evaluate the antibacterial activity of the drug. The test drug was prepared in the Gunapadam laboratory, NIS as per the literature. Standardization of the drug was done as per PLIM Guidelines. Anti-bacterial activity of the drug assessed by Disc diffusion method against *E-coli* and *Proteus mirabilis*. The SOP for the drug was generated and standardization parameters for the drug were under the limits as per PLIM guidelines. The result indicates that the drug has Antibacterial activity against *E-coli* and *Proteus mirabilis*.

Keywords: *Vaazhai Pazha Jayaneer*; *Jayaneer*; Standardization; Anti-bacterial activity Internal medicine.





INTRODUCTION

Siddha medicine is one of the oldest healthcare systems in India, currently gaining recognition in developed countries as well. This system, a unique blend of science and healing art, was developed by revered poet-mystics known as Siddhars, who authored significant texts. The origins of Siddha medicine and the Tamil language are linked to the sage Agasthiyar. Comparable in antiquity to Ayurveda in northern India, the Siddha system thrived in the southern regions. It has also gained popularity in countries such as Sri Lanka, Burma, Malaysia, and other Southeast Asian nations. Historical literature provides evidence of its advanced practice from early civilizations. Notably, several Chinese priests who visited India studied this system from prominent Siddhars, including the renowned Bogar[1-2]. Siddha Medicine harnesses the therapeutic potential of minerals, metallic preparations, and medicinal plants through distinctive chemical processes. These processes transform raw materials into effective therapeutic agents, setting Siddha apart. Various pharmaceutical techniques are employed, including calcination, sublimation, distillation, dissolution, fusion, separation, combination, purification, and incineration. The Siddha System categorizes its preparations into two main groups: 32 internal formulations and 32 external applications, each tailored to specific therapeutic needs[2]. *Jayaneer* is a pungent liquid prepared by exposing the drug to night's dew along with a mixture of powdered lime and ammoniac. It is also said that it is a medicinal preparation of pungent liquid obtained by exposing it to night's dew on a porcelain dish containing a mixture of *Rasthaali* Banana, Limestone and Ashes of banana bark. This *Jayaneer* is peculiar to Tamil Siddha Science and it is a pungent liquid always prepared by exposing medicinal salts, poisonous compounds, etc., to nights' dew. It is supposed to be a solvent medium for many insoluble substances and as such is used for preparing medicines of very high potency and in Alchemy it is chiefly consolidating or fixing up volatile substances. In medicine, it forms a useful medium in the preparation of metallic oxides by the process of calcination. Mid-January to mid-April is a suitable time for preparing *Jayaneer*[3-4]. This study is aimed to analysing the qualitative parameters of *Vaazhai Pazha Jayaneer*(VPJ), a Siddha formulation from *Anuboga Vaithiya Navaneetham*, part IV and also its Anti-bacterial property.

MATERIALS AND METHODS

Selection of the test drugs

The test drug "*Vaazhai Pazha Jayaneer*" is one of the Herbo mineral formulations for *Moothira kiricharam* (Urinary tract infection) which is indicated in the Siddha literature *Anuboga Vaithiya Navaneetham*, part-IV[5].

Collection of Raw drugs

The raw drug was purchased in a Country shop in Chennai and authenticated from the "Department of Gunapadam, National Institute of Siddha, Chennai" (certified No. GUN/AUT/14/24). (Table:1)

Ingredients of *Vaazhai Pazha Jayaneer*:

Preparation of *Vaazhai Pazha Jayaneer*

The banana was separated from its skin and placed into a wide vessel, around 4 kg in total. About 500g of *vaazhai sarugu* ashes and 500g of *karchunnaambu* were added one by one. All ingredients were thoroughly mixed by hand using a crushing method, and then left undisturbed for 4–5 days. The secreted liquid was collected until no more secretion occurred. It was then stored in an airtight glass container[5].

Standardization(By PLIM guidelines):

The evaluation of the quality and purity of herbo-mineral drugs through various parameters, including physical, chemical, and biological observations, is referred to as standardization. The standardization of these drugs is classified into several categories,

1. Organoleptic characters
2. Physico-chemical properties





3. Biochemical analysis

Standardization was determined by the analytical parameters as per PLIM guidelines. [6] The study was done at Interstellar Testing Centre Pvt. Ltd, Panchkula, Haryana.

Organoleptic characters

The organoleptic properties of the sample were assessed, focusing on the formulation's color and odour through visual examination.

Physico-chemical properties

Physico-chemical properties of this drug were assessed by parameters like pH, Optical rotation, Specific gravity, Refractory index (at 25°C), Viscosity, and Boiling point.

Bio-chemical analysis

Bio-chemical analysis of this drug were determined by the analysis like Heavy metal analysis, Aflatoxin analysis and Pesticide analysis are following,

Heavy metal analysis

The presence amount of heavy metals like Arsenic, Mercury, Lead and Cadmium in this drug were assessed by the method Inductively coupled plasma mass spectrometry (ICPMS)[7-8].

Aflatoxins

The presence amount of aflatoxins B1, B2, G1, G2 were assessed by the method High Performance Liquid Chromatography (HPLC)[9-11].

Pesticide residue

The presence amount of pesticides like Organo phosphorous, Organo chloride and Pyrethroids were assessed by the method Gas Chromatography combined with Mass Spectrometry (GS-MS) [12-13].

Anti-bacterial property

Anti-bacterial property of this drug was assessed by Disc diffusion method against the species of *Escherichia coli* and *Proteus mirabilis*.

Disc diffusion method

Escherichia coli (MTCC 443) and *Proteus mirabilis* (MTCC 425) strains were obtained from IMTECH, India. Antimicrobial activity was assessed using disc diffusion (Kirby et al., 1966; CLSI, 2012) with minor modifications. Bacterial laws were prepared on Mueller Hinton Agar plates, and test samples were loaded at various concentrations. After 24-hour incubation at 37°C, antibacterial activity was evaluated by measuring inhibition zone diameters using an antibiotic zone scale. (Himedia, Mumbai, India) [14-16].

RESULTS

Standardization of *Vaazhai pazha Jayaneer*

Organoleptic characters

The organoleptic characteristics of *Vaazhai Pazha Jayaneer* are recorded in Table 2.

Physico-chemical analysis

The physico-chemical characteristics of *Vaazhai Pazha Jayaneer* are documented in Table 2.



**Bio-chemical analysis****(i) Heavy metal analysis**

The heavy metal analysis of *Vaazhai Pazha Jayaneer* is presented in Table 4.

(ii) Aflatoxins

The amount of aflatoxins in *Vaazhai Pazha Jayaneer* (VPJ) is summarized in Table 5 [].

(iii) Pesticide residue

The pesticide residue in *Vaazhai Pazha Jayaneer* (VPJ) is recorded in Table 6.

(BLQ - Below Limit of Quantification; BDL - Below Detection of Limit)

Anti-bacterial property

The antibacterial activity of test sample showed antibacterial activity against *Escherichia coli* and *Proteus mirabilis* tested type strains. The anti-bacterial activity of the test sample control can be visualized in the picture.

DISCUSSIONS

Jayaneer is a pungent liquid prepared by exposing to night's dew a mixture of powdered limestone and Sal ammoniac. It also said to be used in Alchemy-philosopher's acid. *Jayaneer* is used to prepare the higher order medicines. Basically, *Jayaneer* is alkaline in nature and it has pungent odour by itself. This *Vaazhai Pazha Jayaneer* is obtained by exposing to night's dew on a porcelain dish containing a mixture of *Rasthaali* banana, Ashes of dried banana barks and powdered limestone. *Jayaneer* doesn't evaporate, it changes the metals into atomic levels, and *Jayaneer* always steadily withstands in high temperatures. Standardization of the drug was done as per PLIM guidelines. The results of the standardization gave more information about this *Jayaneer*. Result of pH value indicates that this *Jayaneer* is highly alkaline (pH-12.95). Specific gravity of the *Jayaneer* was 1.1841. It indicates that this *Jayaneer* is slightly denser than water. The heavy metal content (Arsenic, Lead, Cadmium, Mercury), Pesticide residue (Organo chloride, Organo phosphate, Pyrethroids) are in low limit in this *Jayaneer*. It indicates that this drug was safe to consume and can be used in medicine preparation. The total viable aerobic count and total fungal count are very remarkable and their values are in acceptable limits as per PLIM guidelines. It indicates that the drug is safe to consume. A urinary tract infection (UTI) occurs when any component of the urinary system, comprising the kidneys, ureters, bladder, and urethra, becomes infected. Typically, the infection affects the lower urinary tract, specifically the bladder and urethra. Notably, females have a higher susceptibility to developing UTIs compared to males. The common Urinary Tract infection-causing pathogens are *Escherichia coli* and *Proteus mirabilis*. The Anti-microbial activity of the drug *Vaazhai Pazha Jayaneer* was assessed through the disc diffusion method against *Escherichia coli* and *Proteus mirabilis*. The anti-bacterial activity of the drug was assessed through the disc diffusion method. Nowadays, the most common Urinary Tract infection-causing pathogens are *Escherichia coli* and *Proteus mirabilis*. According to the result of the disc diffusion method, the zone of inhibition was well formed against *Escherichia coli* and *Proteus mirabilis*. The results are close to the standard drug Azithromycin. It is clearer that the medicine *Vaazhai Pazha Jayaneer* has good anti-bacterial activity and is effective against Urinary Tract Infections.

CONCLUSION

In the present study, Standardization as per PLIM guidelines of the drug *Vaazhai Pazha Jayaneer* has been established. All the parameters were under the limits that proved the drug was safe to consume. The drug possessed good Anti-bacterial activity against the urinary pathogens, *Escherichia coli* and *Proteus mirabilis*. The drug has been indicated for processing metallic and mineral formulations. Further in-vivo studies have to be carried out to confirm its therapeutic effect on Urinary tract infections.



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Conflict of Interest

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Table:1 Ingredients of Vaazhai Pazha Jayaneer

S. No	The vernacular name of the ingredients	Botanical name/Chemical name	Quantity
1.	Rasthaali Vaazhai Pazham	<i>Musa acuminata</i> Colla	4kg
2.	Karchunnaambu	Limestone	500gm
3.	Vaazhai sarugu sutta saambal	Ashes of banana bark	500gm

Table:2 Results of organoleptic characters of VPJ

Colour	Brown
Odour	Pungent

Table:3 Results of Physico-chemical analysis of VPJ

pH	12.95
Refractory index (at 25°C)	1.383
Optical rotation	0.121°
Boiling point	107°C
Specific gravity	1.1841
Viscosity	300cps

Table:4 Results of Heavy metal analysis of VPJ

Arsenic	0.13ppm (BBQ)
Mercury	0.25ppm (BBQ)
Lead	0.10ppm (BLQ)
Cadmium	0.10ppm (BLQ)

Table:5 Results of aflatoxin analysis in Vaazhai Pazha Jayaneer (VPJ).

B ₁	0.005ppm (BDL)
B ₂	0.005ppm (BDL)
G ₁	0.005ppm (BDL)
G ₂	0.005ppm (BDL)

Table: 6 Results of pesticide residue in VPJ

Malathion	0.005ppm (BDL)
Methidathion	0.005ppm (BDL)
Parathion	0.005ppm (BDL)
Parathion methyl	0.005ppm (BDL)
Phosalone	0.005ppm (BDL)
Pirimiphos - methyl	0.005ppm (BDL)
Azinphos - methyl	0.005ppm (BDL)
Chlorpyrifos	0.005ppm (BDL)
Chlorpyrifos - methyl	0.005ppm (BDL)
Diazinon	0.005ppm (BDL)
Alpha - Hexachlorocyclohexane	0.005ppm (BDL)

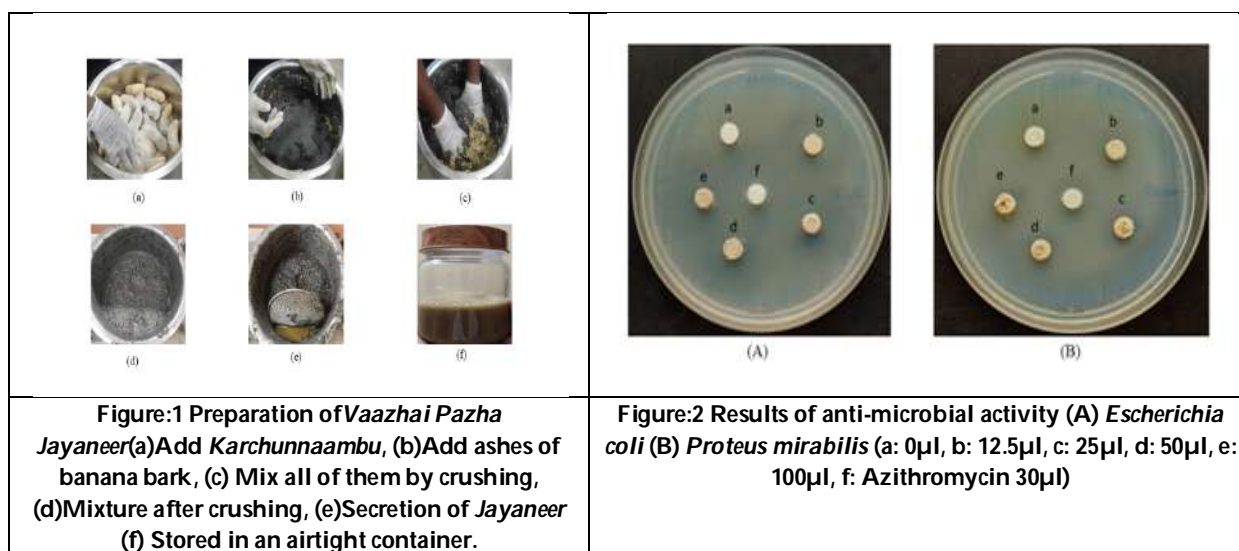




Lindane	0.005ppm (BDL)
Delta - Hexachlorocyclohexane	0.005ppm (BDL)
Heptachlor	0.005ppm (BDL)
Cis - Heptachlor - epoxide	0.005ppm (BDL)
O, p'' – DDE	0.005ppm (BDL)
Alpha - Endosulfan	0.005ppm (BDL)
Beta - Endosulfan	0.005ppm (BDL)
Carbophenothion	0.005ppm (BDL)
Cis - permethrin	0.005ppm (BDL)
Trans - permethrin	0.005ppm (BDL)
Cypermethrin	0.005ppm (BDL)
Beta - Hexachlorocyclohexane	0.005ppm (BDL)
Gamma - Hexachlorocyclohexane	0.005ppm (BDL)
P, P – DDE	0.005ppm (BDL)
O, P - DDT	0.005ppm (BDL)
P, P - DDT	0.005ppm (BDL)

Table:7 Results of Anti-bacterial property in VPJ

Name of the organism	Zone of Inhibition (mm)					Standard (Azithromycin)
	0µl	12.5 µl	25 µl	50 µl	100 µl	Zone of Inhibition
<i>Escherichia coli</i>	-	13	15	16	18	30 µg
<i>Proteus mirabilis</i>	-	9	10	11	12	23
						17





Social Media Influence Maximization using Convolutional Neural Network and Recent with Graph Neural Networks

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ABSTRACT

People are increasingly connected around the world through online social networks. A hot research area in online social networks is influence maximization, which is aimed at finding influential users in the dissemination process of information. In recent years, people around the world have accelerated in connecting to online social networks than before using social networks. Recently, Facebook, Instagram, YouTube and other social platforms as a whole have been gradually integrated into people's lives. In recent years, online social networks have become a hot research topic with inextricable links to data mining and machine learning. Here influence means given user as well as his or her posts have power to change cognitive states of others. Typically, users modify their original cognitions under social network dynamics affected by other users'. The influence of social media is mostly rooted the word of mouth effect and viral marketing. In this paper we are using enhanced Convolutional Neural Network (CNN) and ResNet with Graph Neural Networks (GNN) algorithms to investigate the largest user effects on Facebook, Instagram, and YouTube. Accuracy, precision, recall, and F-measure scores indicate the fastest increasing influencers on Facebook, Instagram, and YouTube. **The proposed achieve 98.67% accuracy in facebook dataset, 98.57% accuracy in Instagram dataset, 98.34% accuracy in YouTube dataset.** The result shows Instagram had the largest user growth between 2023 and 2024.

Keywords: Convolutional Neural Network, Deep Learning, ResNet with Graph Neural Networks, Influence maximization, Online Social Networks

INTRODUCTION

Social media has developed dramatically in the previous 10 years, with big sites like Twitter, Facebook, YouTube, and Instagram multiplying [1]. People use social networking sites to freely and informally share their ideas, opinions, loves, hates, and experiences [2–4]. As Artificial Intelligence (AI) advances, Convolutional Neural Networks (CNNs)



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enable computers to learn by overcoming information scarcity and training complex models on larger data sets, as described in various studies [5-9]. Social media websites have emerged as primary media channels for the dissemination of personal information, news, photographs, and videos, among other things. People may still share live broadcasts when they want to communicate with a large group of people [10]. Because of its extensive use, companies, data analysts, and academics have been trying to extract insightful analysis from the enormous volume of data produced by social media. Knowledge dissemination and word-of-mouth propagation [11-13] are two of the most important subjects of interest for social media academics. User modeling, viral marketing, content development, and user suggestions are just a few of the uses this material might find. Social media is currently the primary means of sharing personal information, images, videos, news, and other content. Every day, social media users devote countless hours [14-16]. Businesses and marketers are eager in this as it offers a free approach to contact many consumers. The most popular fields of social media mining research are influence and sentiment analysis. Both categories may assist businesses with their marketing initiatives [17-19]. Similar to impact analysis, researchers evaluate social media information diffusion models to identify key individuals that facilitate knowledge exchange. Recommender systems may help with this information by directing customers interested in certain topics to appropriate authorities [20]. One of the most important tactics for doing this is to disseminate information and use influential individuals, since brand recognition and campaign performance may considerably improve [21-23]. People's daily lives are heavily impacted by digital networks; hence many new academics are looking into this rapidly increasing issue across several sub-domains. The first obvious difficulty that a researcher addresses as social networks grow more prominent is how to get specific data from the sources. This encourages marketers to use SM to discover new ideas and consumer trends. [24]. In this paper, we are going to examine enhanced Convolutional Neural Networks DCNN and ResNet with GNN networks for Facebook, Instagram, and YouTube's influencers' maximization. Why these three because these three social media are rapidly growing platforms. We look up multi neural networks for Influence maximization of Facebook, Instagram, and YouTube.

BACKGROUND STUDY

Bhattacharya R., et al., (2023) these authors proposed Graph Convolutional Networks (GCN) based on Deep Learning to find significant nodes in large-scale graph datasets. Using structural centrality in concert with Graph Convolutional Networks, the DeepInfNode deep learning approach produced strong nodes. The GCN method produces node representations by assessing contextual information from trials in the Susceptible-Infected-Recovered (SIR) model. Since they only take network topology or node characteristics, traditional approaches include centrality or machine learning are quite restricted in their applicability. To address this obstacle, these authors offer the DeepInfNode graph convolution learning model for the most influential nodes and reinterpret the framework for identifying these nodes as a classification issue. Bhavnani, V., et al (2021) these authors used the Gaussian kernel approach and the grey wolf optimization methodology to perform a thorough analysis of various current techniques and methods for locating significant nodes utilizing the Singular value Decomposition (SVD)-rank and Singular value Decomposition adjusted (SVDA)-rank algorithms. Positive and negative indicators in the Gaussian kernel approach showed user influence or lack. Using wolves-like criteria, an optimum solution was found in the grey wolf optimization approach. It has been noted that researchers change the methods that provide better findings with more precision than in the times. Chen, L., et al. (2022) these researchers introduced a novel network model called the effect-based Bi-Directional network Convolutional Network (Bi-GCN), which captures user influence and how rumors propagate. First, independent evaluation of their local and global impacts using an information entropy-based approach was done before determining the weighted total of users. Second, these authors integrate the two main aspects of rumor spread and transmission with the general influence factor. They developed a high-level representation for bidirectional graph convolutional neural network rumor detection. Gammoudi, F., et al (2022) intimate interactions, such as those with friends, family, or coworkers, have a direct influence on social media users. Those that follow them via shared information, goals, news, and perspectives may likewise have an impact on them. Often, an influencer was someone who convinced an influence to keep up an activity, make the same choice, or modify their conduct. There are many tools available to assist in the search for strong individuals. These researchers examined the challenge of finding SM influencers in the framework of SM impact. They began by conducting a literature study to assess the influence of social media. Following that, these authors organized the works and



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highlighted the greatest literary masterpieces to assist in locating social media superstars. Jothi, P., et al (2022) the Influencer User Prediction (IUP) problem was addressed by the authors using a CNN approach. New centrality measurements was first calculated and compiled. Following that, further important indicators were picked using the Gray Wolf (GW) technique, from which CNN learned to fairly accurately predict notable persons. Furthermore, this strategy was tested on Facebook with an analysis of around 5000 tweets from various disciplines (news, education, politics, sports, and entertainment). They introduced new metrics by linearly aggregating the provided centrality values. The GW search method was advised for identifying the most relevant features for members of an Online Social Network (OSN) based on position updates and fitness value. Grey Wolf Optimizing Convolutional Neural Network (GW-CNN) system employs acquired influence maximization from CNN's MSE as its fitness function. The IUP was therefore given without adding computing complexity. Liu, W., et al (2024) these authors provide a novel IM approach and reinterpret the Influence Maximising (IM) problem as a regression analysis. The approach examines the network's latent topological information using an adaptive graph convolution neural network, resulting in significantly improved performance. They present an efficient algorithm based on an adaptive graph Convolutional Neural Network that combines several network-level attributes and some centrality measurements into a vector that serves as the presentation vector for nodes in the social network after the IM problem is converted into a regression problem. Following the extraction of several heuristic measurements and attribute features from the network, these authors embed nodes to get representation vectors in Euclidean space. Their unique heuristic technique, Neighbour Domain Discount (NDD), identifies additional components beyond discounted degrees. Labels and embeddings added to a training set enable the recommended model to be used to project node target network effects. Luceri, L., et al (2019) these authors investigated human real-life conduct via the lens of social influence on offline dynamics.

They demonstrated Social Influence Deep Learning (SIDL), a method that combines DL and network research to assess social influence and predict human conduct during real events or site visits. To address two major difficulties in Deep Learning: interpretability and scalability, they proposed a variety of techniques with varying levels of network connection. Their methods were tested and evaluated against data from Foursquare, a location-based social networking site, and Plan cast, an event-based social network. Finally, they investigate several DL architectures and the relationship of social influence and user privacy, drawing findings as well as warnings about the risks of broadcasting private data. Qiu, J., et al (2018) these authors analyzed personal real-life situations via the lens of social effect on offline dynamics. Social Reperfection Combining network research with Deep Learning, which analyses social effect and predicts human behaviour during live events or site visits, they address the two major DL issues, interpretability and scalability, by providing a variety of strategies with varying degrees of network connectivity. Data from Foursquare, a location-based social networking site, and Plan cast, an event-based social network, enabled these authors to evaluate their methodologies. Finally, they examine several Deep Learning systems and the relationship between social influence and user privacy, generating findings as well as warnings about the risks of disclosing personal information. Thunuguntla, S. B., et al (2023) these authors provided a strategy for analyzing internet picture advertising. First, from the supplied advertisement picture, extract the items and advertising words. Use DenseNet-121 then to categorize ads based on their characteristics. Following that, data from advertisement classification results and a Deep Neural Network (DNN) approach were utilized to recommend advertisements to specific users based on their preferences. Tran, Q. M., et al (2022) these authors presented a measure to assess how individuals and organizations influence social media platforms. Knowledge graph approaches should be used with Deep Learning. Someone constructed a fantastic Knowledge Graph specifically to display user interaction activities. A variational graph-based unsupervised DL model autoencoder was created to better assess user activity. The model inspired by the conventional graph convolutional layer. It aggregates user attributes while also learning from their interactions. The model worked with unknown data and required little labeling effort. When collecting the dataset, a custom crawling algorithm ensures that it was current and fashionable for this purpose. When compared to various well-known graph-convolutional-based models, the tests show incredible performance and promising results.



**Karthekeyan et al.,****Problem Identification**

Existing Convolutional Neural Networks need a large amount of labeled data and have much slower training periods. Thus, in this study, we optimize the social media influence maximization effect by using enhanced Convolutional Neural Network and ResNet with GNN algorithms, so boosting the performance of Investigate.

MATERIALS AND METHODS

This chapter, particularly in connection to multi neural networks, discusses the ideal effect maximization in the field of inquiry of social media. After data preparation is complete, collect the three types of datasets from kaggle datasets. This research aims to include the GNN approach into enhanced Convolutional Neural Networks (CNN) and ResNet models, therefore increasing their capacity. This strategy is believed to be critical for increasing the efficiency and effectiveness of influence-maximizing strategies in the complicated terrain of social media networks. Among other social media sites, the figure 1 shows how to find notable individuals on Facebook, Instagram, and YouTube. First data collecting starts when user interactions and engagement on these websites rise. After that, this information is examined to better grasp user behavior and spot important factors as follower count and interaction rates. These qualities help the system to find important users that is, those who significantly affect other people. Furthermore included in the method is network analysis to examine user impact dispersion. At last, the findings are reviewed and polished to raise the influence detection accuracy.

Dataset Collection

Kaggle dataset sets provide the data for social influence maximizing. For

- Facebook: <https://www.kaggle.com/datasets/sheenabatra/facebook-data>
 - Instagram: <https://www.kaggle.com/datasets/krpurba/im-instagram-70k>
 - YouTube: <https://www.kaggle.com/datasets/kathir1k/youtube-influencers-data>
- Datasets provide valuable insights, trends, and forecasts. This session looks at three distinct kinds of datasets from various sectors to demonstrate the breadth of applications for data analysis and machine learning.

Data Preprocessing

Several critical steps must be followed while preparing a dataset for machine learning to ensure that the data is suitable for effective model training and testing. This process begins with raw data input into the programming environment, followed by Exploratory Data Analysis (EDA), which identifies trends, anomalies, and patterns. This stage corrects missing numbers, inconsistencies, and errors to enhance data quality. Standardizing or normalizing numerical features ensures that they contribute equally throughout model building. Class imbalances are handled using approaches like as weighting or resampling to ensure equal model performance across classes. Training and testing sets are then split out from the dataset to enable an objective evaluation of model performance. Maintaining openness and reproducibility in research requires proper documentation of these procedures, which leads to more reliable and interpretable machine learning outcomes.

Social Media Influence Maximization using enhanced Convolutional Neural network and Resnet with Graph Neural Networks

An enhanced CNN and ResNet with GNN are used for social media influence maximization process. Enhanced CNN consists basically of three layers: convolutional, fully connected, and pooling layers. The convolutional layer, works largely via the dot product of receptive fields and a collection of learnable filters, or kernels. Figure 2 shows convolution. Pooling layer nonlinear downsamplings allow you to lower data dimension after convolution. The two most common pooling strategies used now are average and maximum pooling. Currently, average and maximum pooling are the two most used approaches of pooling. Max pooling finds the candidates with the highest potential value, while average pooling finds their average value. Following downsampling of the feature maps, nonlinear transformations such as the Rectified Linear Unit are used to activate circuits. The heavily linked layer then finishes the higher-order thinking. The neurones of this layer react to the entire stimulus generated underneath. The loss





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layer, which is often the last layer of an enhanced CNN, determines how the network learns to punish the discrepancy between predicted and actual social media influencer labels. A variety of loss functions, such as sigmoid cross-entropy loss and softmax loss, may aid in the completion of numerous tasks. The term "neurone" is often used in software and algorithm development. A basic operational unit in enhanced CNNs is one or more. ResNet CNN models are made up of four transition layers and five blocks. The training dataset, which has a kernel size of 7x7, serves as the initial input for the convolutional layer utilized for feature extraction. A 3x3 max pooling layer contributes to the reduction of feature maps by aggregating acquired features. They then produce dense-1, which includes additional features and has six convolutional layers with kernel sizes of 1 x 1 and 3 x 3. Low input feature maps assist to blend the properties of each channel while also increasing processing efficiency. The prediction of influencer maximization process is performed by combining enhanced CNN, ResNet with GNN. The vast number of layers allows for effective value prediction. This method performs well with the multiple layers used enhanced CNN and ResNet with GNN. The Neural is a computational unit that takes as input $x_1 x_2 x_3$ and outputs $h_{w,p}(x) = f(W^t x) = f \sum_{i=1}^3 w_i x_i + p$, where f is activation function. $f(\cdot)$ is to be sigmoid function

$$f(x) = \frac{1}{1 + \exp(-y)} \quad \text{----- (1)}$$

As a result, the input-output mapping produced by logistic regression applies to single neurones.

And use the sigmoid function for f is the hyperbolic tangent or tanh:

$$f(x) = \tanh(y) = \frac{e^y - e^{-y}}{e^y + e^{-y}} \quad \text{----- (2)}$$

In Convolutional Neural Networks, the activation function performs better in practice. This activation function is neither restricted nor continuously differentiable, unlike the sigmoid and tanh functions. The proper activation function is:

$$f(y) = \max(0, x). \quad \text{----- (3)}$$

Originally a rescaled variant of sigmoid, the tanh (y) function produces values between [-1, 1] rather than [0, 1]. When the input y is less than 0, the piecewise linear function saturates at exactly 0.

The sigmoid function

$$f(z) = \frac{1}{1 + \exp(-y)} \quad \text{----- (4)}$$

Its derivation is (5) and if f is the tanh function then it is (6)

$$f'(y) = f(y)(1 - f(y)) \quad \text{----- (5)}$$

$$f'(y) = (1 - f(y))^2 \quad \text{----- (6)}$$

When $y < 0$, the adjusted activation function has gradient 0, otherwise it has gradient 1. In practice, however, this does not cause problems since the gradient over several training cycles is undefined at $y=0$. Figure 2 shows a deep learning process might be used to find resources or investigate social media. It begins with collecting data from Instagram, Facebook, and LinkedIn among other social media sites. Most frequently an enhanced Convolutional Neural Network, the data then moves throughout a succession of layers in a neural network. We compile and interact with data characteristics at many stages. Following further layers such deep layers that allow the construction of predictions or classifications reveals the traits under research. At last the model is tested, and recommendations abound for raising its accuracy and performance.

Algorithm 1: Enhanced CNN and ResNet with GNN Algorithms

Input: Dataset D

Step 1: Generate training dataset

Step 2: Preprocessing

Cleaning the data, and handling categorical data

Step 3: Splitting the data

Divide data into training and validation

Step 4: Training

Define model architecture and hyperparameters then training on training dataset

Step 5: Evaluate Performance

Choose correct metric and Evaluate on validate set

Step 6: if (satisfied)





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Deploy output

Else

Tune hyperparameters

Step 7: Repeat step 4**Output:** Maximization result

The enhanced CNN approach begins with a dataset D. Create a training set next Cleaning and dividing happen. The first hyperparameter settings and dataset training have been completed. Hyperparameters are settings or configurations that are established before to the commencement of the training process. Afterwards, the assessment on the training dataset will utilize the output if the validated data is satisfied; else, it will tweak the hyperparameters, train the dataset again, and create the output.

RESULTS AND DISCUSSIONS

Result shows enhanced Convolutional Neural Networks, ResNet GNN improvements in identifying critical nodes in Facebook, Instagram, and Youtube. In this study, we assess algorithm performance using Python. Given both local and global implications, our hybrid method captures user interactions more effectively than traditional models such as existing CNNs. The combined model achieves higher accuracy, precision, and recall metrics, highlighting its ability to discriminate influential users from non-influential ones. Enhanced CNN paired with ResNet architecture provides a more accurate image of user interactions and effect distribution. The GNN component enhances the model by enabling it to account for both forward and backward influence flows into the network. Table 2 shows the Users and Influencers growth in Facebook, Instagram, and YouTube from year 2018 to 2024. The number of users is increased in instagram from 2023 to 2024 but the influencer's growth is low compared to Facebook, and YouTube. Facebook has the highest user growth and steady influencer's growth. YouTube has the steady user and influencer's growth. Figure 3 shows the user and Influencers growth in Facebook, Instagram, and YouTube from year 2018 to 2024. The User and Influencers base is higher in Facebook and YouTube compared to Instagram. In recent days the user's growth is increasing in instagram. In this chart year from 2018 to 2024 is given in the x-axis and y-axis shows the count of user and influencers.

Performance evaluation

Accuracy

In predictive modeling, accuracy is the measure of how close the model's projections are to the actual outcomes. It quantifies the model's dependability and accuracy, which is critical for making predictions and judgments in a variety of contexts.

T-True, F-False, P-Positive, N-Negative

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \text{ ----- (7)}$$

Precision

In predictive modeling, accuracy is the proportion of total expected positive observations to correctly forecasted positive observations. It displays how effectively the model lowers false positives, ensuring the genuine accuracy and reliability of the positive predictions it generates—qualities necessary for decision-making and, as a result, error reduction in many other domains.

$$Precision = \frac{TP}{TP+FP} \text{ ----- (8)}$$

Recall

Recall in predictive modeling is the fraction of real positive instances the model properly detected. It is valuable in industries like medical diagnosis or fraud detection where identifying all positives is rather important because it shows how well the model detects all relevant cases of a particular class.





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$$\text{Recall} = \frac{TP}{TP + FN} \text{ ----- (9)}$$

F-measure

The F-measure, which calculates the harmonic mean of accuracy and recall, provides a comprehensive assessment of a model's performance, particularly in cases where both false positives and false negatives must be avoided.

$$F - \text{measure} = 2 \times \frac{\text{Precision} \times \text{recall}}{\text{precision} + \text{recall}} \text{ ----- (10)}$$

Table 3 compares different performance metrics for various algorithms (CNN, enhanced CNN, ResNet, GNN, ResNet with GNN, and Enhanced CNN and ResNet with GNN) using Facebook data. The metric values show that accuracy is the highest among all metrics. Figure 4 illustrates Facebook's performance metrics using various algorithms (CNN, enhanced CNN, ResNet, GNN, ResNet with GNN, and Enhanced CNN and ResNet with GNN). The proposed methods accuracy is highest compared to other methods. In this plot diagram the x-axis shows the different algorithms and the y-axis shows the values of the metrics. Table 4 compares different performance metrics for various algorithms (CNN, enhanced CNN, ResNet, GNN, ResNet with GNN, and Enhanced CNN and ResNet with GNN) using Instagram data. The metric values show that accuracy is the highest among all metrics. Figure 5 illustrates Instagram's performance metrics using various algorithms (CNN, enhanced CNN, ResNet, GNN, ResNet with GNN, and Enhanced CNN and ResNet with GNN). The accuracy is highest compared to other metrics. The x-axis shows the different algorithms and the y-axis shows the values of the metrics. Table 5 compares different performance metrics for various algorithms (CNN, enhanced CNN, ResNet, GNN, ResNet with GNN, and Enhanced CNN and ResNet with GNN) using YouTube data. The metric values show that accuracy is the highest among all metrics. Figure 4 illustrates YouTube's performance metrics using various algorithms (CNN, enhanced CNN, ResNet, GNN, ResNet with GNN, and Enhanced CNN and ResNet with GNN). The accuracy is highest compared to other metrics. The x-axis shows the different algorithms and the y-axis shows the values of the metrics.

CONCLUSION

In conclusion, Multi Deep Neural Networks helps to discover and enhance social media impacts when coupled with an enhanced CNN and ResNet with GNN. Combining the features of every paradigm helps ResNet to guarantee effective gradient propagation and information flow all across the network. While enhanced CNNs help to extract entire features from big datasets, GNN detects contextual links in both directions. These models taken together provide a strong basis for assessing user interactions, identifying key players, and customizing strategies to optimize impact on Facebook, Instagram, and Youtube. This method lets content strategies and focused outreach change, thus improving the accuracy and range of impact evaluations. The results show the accuracy, Precision, Recall, F-measure values of Facebook, Instagram, and YouTube. Using proposed enhanced CNN and ResNet with GNN outperforms with the accuracy 98.67% in facebook dataset, 98.57% accuracy in Instagram dataset, 98.34% accuracy in YouTube dataset compared to other existing methods. Future studies aiming at quantifying the influencer effect on social media will assist to improve the performance of enhanced CNN and ResNet with GNN.

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Table 1: Comparison table For DCNN and BiCNN

Authors / years	Method/Model	Key Techniques	Applications/Context	Results/Insights
Bhavnani et al. (2021)	SVD-rank, SVDA-rank, Grey Wolf Optimization	Gaussian Kernel, Grey Wolf Optimization	Bipartite Networks	Observed improved accuracy in Detecting influential nodes over time with methodological modifications.
Chen. L., (2022) et al.	Influence-based Bi-Directional GCN (IBi-GCN)	Information Entropy, Bi-Directional GCN	Rumor Propagation and Detection	Uses information entropy to capture local/global influence for Improved rumor detection.
Gammoudi et al. (2022)	Social network analysis (SNA)	Overview of Social Media Influence (SMI) Tools	Social Media Influencer Identification	Provides a generic overview of SMI.
Jothi et al. (2022)	CNN Framework (IUP)	Centrality Measures, GW Algorithm, CNN	Influential User Prediction in Facebook	Applied CNN to predict influential users with minimized computational costs.
Bhattacharya (2023)	DeepInfNode (Graph Convolutional Networks)	GCN, SIR model trials	Influential Node Identification	Measures structural centrality using GCN, recasting node identification as a classification problem.
Liu et al. (2024)	Adaptive Graph Convolution Neural Network (IM)	Regression, Adaptive GCN, Heuristic Measures	Influence Maximization	Integrates network attributes and centrality metrics for efficient node influence prediction.

Table 2: Comparison table for Facebook, Instagram, YouTube users from year 2018 to 2024

Year	Facebook Users	Facebook Influencers (Estimate)	Instagram Users	Instagram Influencers (Estimate)	YouTube Users	YouTube Influencers (Estimate)
2018	2.23 billion	6 million	1 billion	500K	1.9 billion	10 million
2019	2.45 billion	7 million	1.2 billion	600K	2 billion	11 million
2020	2.80 billion	9 million	1.3 billion	750K	2.3 billion	12 million
2021	2.91 billion	10 million	1.4 billion	900K	2.6 billion	13 million
2022	2.93 billion	11 million	1.5 billion	1 million	2.7 billion	14 million
2023	2.96 billion	12 million	1.7 billion	1.2 million	2.8 billion	15 million
2024	3.0 billion	13 million	1.9 billion	1.4 million	2.9 billion	16 million





Table 3: Performance analysis comparison for Facebook

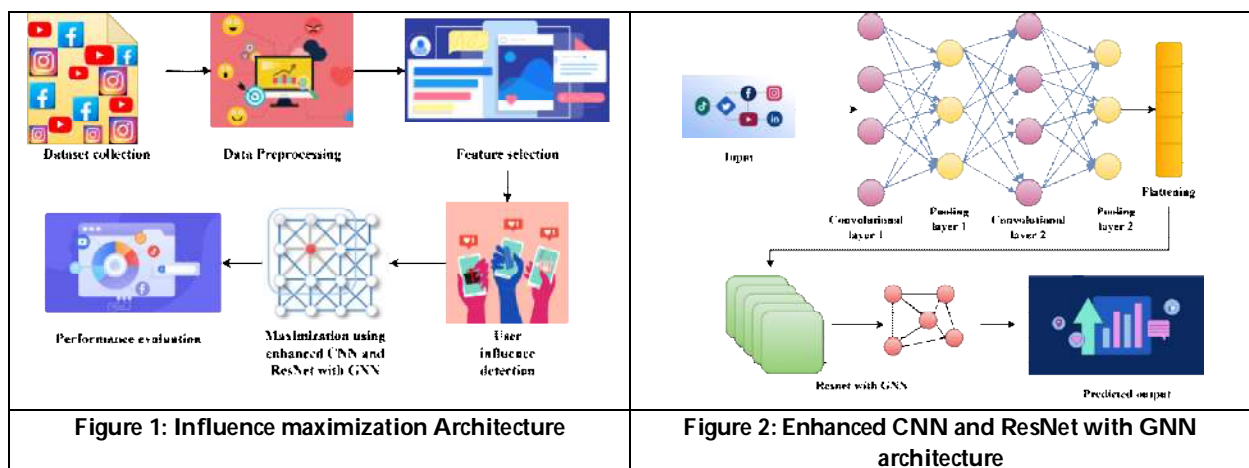
Algorithms/ Metrics	Accuracy	Precision	Recall	F-measure
CNN	95.20	95.00	95.11	94.92
Enhanced CNN	95.71	95.23	95.46	95.03
ResNet	96.39	96.11	96.24	96.00
GNN	97.56	96.89	97.11	96.62
ResNet with GNN	97.93	97.56	97.72	97.23
Enhanced CNN and ResNet with GNN	98.67	98.29	98.43	98.10

Table 4: Performance comparison of Instagram

Algorithms/ Metrics	Accuracy	Precision	Recall	F-measure
CNN	94.91	94.43	94.86	94.12
Enhanced CNN	95.89	95.47	95.66	95.11
ResNet	96.21	95.97	96.04	95.78
GNN	96.78	96.54	96.57	96.24
ResNet with GNN	97.80	97.44	97.76	97.10
Enhanced CNN and ResNet with GNN	98.57	98.20	98.45	98.00

Table 5: Performance comparison of YouTube

Algorithms/ Metrics	Accuracy	Precision	Recall	F-measure
CNN	94.30	94.20	94.25	94.00
Enhanced CNN	95.98	95.56	95.70	95.20
ResNet	96.78	96.32	96.50	96.22
GNN	97.32	96.97	97.11	96.58
ResNet with GNN	97.89	97.45	97.65	96.32
Enhanced CNN and ResNet with GNN	98.34	97.98	98.10	97.86



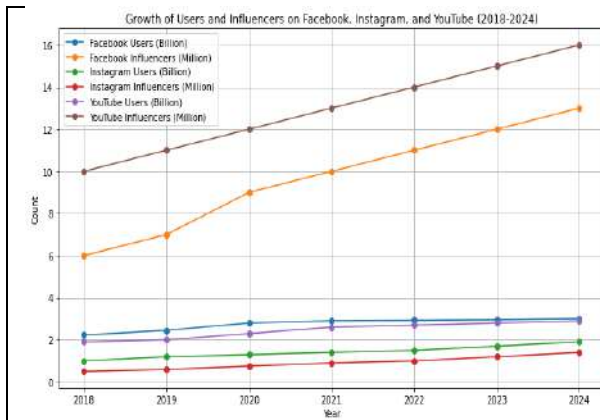


Figure 3: User and Influencers growth in Facebook, Instagram, and YouTube

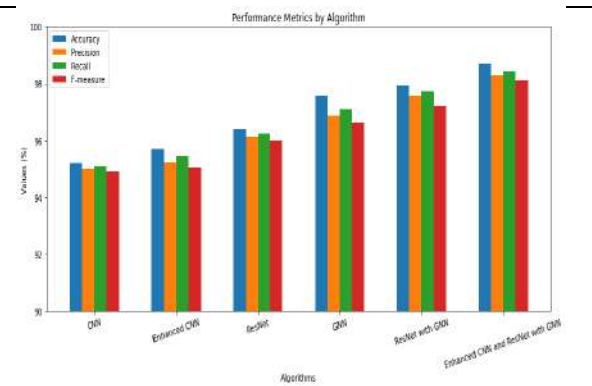


Figure 4: Facebook performance metrics using various Algorithms

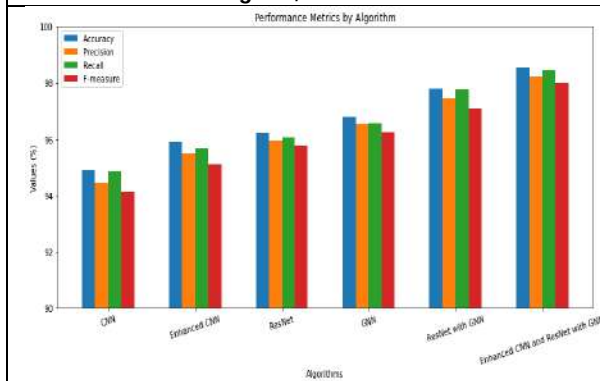


Figure 5: Instagram performance metrics using various Algorithms

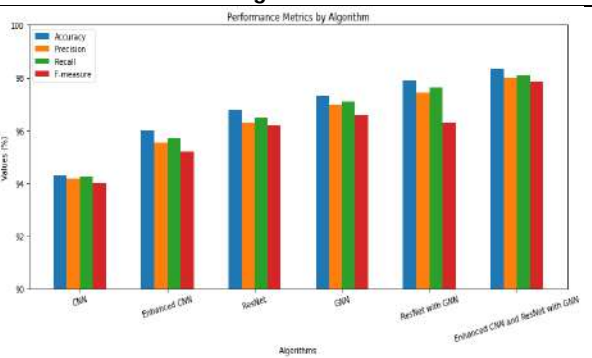


Figure 6: YouTube performance metrics using various Algorithms





Suicide Investigations through Psychological Autopsy: Trends and Future in Forensic Science

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ABSTRACT

This paper tries to explore the role of psychological autopsy as a vital tool in suicide investigation, focusing on how it enhances our understanding of mental states leading to suicide and its implications for forensic science. It examines recent trends in psychological autopsy, where qualitative insights from interviews, medical histories, and digital footprints are used to reconstruct an individual's emotional and cognitive processes before death. These are highlighted to be the massive contributions made by psychological autopsy on risks and motivations that remain left behind in traditional forensic techniques. In addition, the paper discusses the future of psychological autopsy in the evolving field of forensic science. The integration of emerging technologies such as Artificial Intelligence and Machine Learning may improve the analysis of complex psychological data, thereby providing timely interventions and preventive strategies. Ultimately, this study concludes that psychological autopsy, enhanced by modern technological tools, is essential for deepening our understanding of suicide, offering critical insights for both forensic investigations and mental health interventions.

Keywords: Psychological Autopsy, Suicide Investigation, Forensic Science, Mental Health, Artificial Intelligence, Machine Learning.

INTRODUCTION

Psychological autopsy, often referred to as a "psychological reconstruction," is an investigative tool used to analyse and understand the cognitive and emotional processes that may have led to an individual's death, particularly in





cases of suicide[15]. It is a comprehensive evaluation that draws on multiple sources of information, including interviews with friends and family, medical records, and prior psychological assessments[15]. This method allows forensic experts and investigators to accumulate a narrative that sheds light on the deceased's mental state prior to death, filling in the gaps left by traditional investigative techniques[15]. Understanding this complex concept is crucial in today's context, where mental health issues and suicide rates are alarmingly increasing. Historically, the concept of psychological autopsy can be traced back to the influential work of Edwin S. Shneidman, who emphasized its utility in understanding suicidal behaviour[18]. Over the years, the forensic applications of psychological autopsy have broadened, and recent advancements in research methodologies have spurred renewed interest in this technique, particularly in the realm of forensic science. Psychological autopsy is a deeply insightful process that delves into the life of an individual who has passed away, examining their psychological makeup, behavioural tendencies, and the significant events leading up to their death[15]. This thorough investigation allows forensic psychologists to compile detailed reports that shed light on the individual's mental state, potential motivations, and various other elements that may have influenced their demise [1]. This method proves invaluable to investigative agencies, especially in cases involving uncertain death circumstances and suicides[1]. Recent trends have highlighted the increasing recognition of psychological autopsies as indispensable in forensic investigations. Traditional investigative approaches predominantly focused on physical evidence; however, the growing acknowledgment of the psychological dimensions of crime has prompted many forensic experts to incorporate psychological autopsy into their toolkit. This shift towards a more holistic understanding of cases involving suicide reflects a broader trend in forensic science that recognizes the need to assess not just the actions leading to death, but also the complex psychological landscapes of individuals. In many cases, psychological autopsies have provided crucial insights into the motivations and thoughts that culminated in suicidal behaviour, which may not be apparent from physical evidence alone [11].

Psychological Autopsy: Definition And Objectives

Psychological autopsy refers to the post-mortem evaluation of a deceased person's psychological state, primarily in cases of unexplained deaths, suicides, or suspected homicides[15]. It serves several objectives:

- **Understanding Motivations:** It aims to reconstruct the mental and emotional state that could have influenced the individual's actions leading up to their death.
- **Legal and Forensic Applications:** It provides critical information that can assist in legal cases, clarifying whether a death was indeed a suicide and if there are any liability implications.
- **Prevention Strategies:** Insights gained can contribute to developing preventive measures for mental health issues, guiding healthcare professionals in identifying at-risk individuals [16].

Psychological Autopsy: Overview

The concept of psychological autopsy serves as a unique and critical tool in forensic science, particularly in the investigation of suicide cases [19]. This method involves a retrospective analysis aimed at identifying the psychological state of an individual at the time of their death, with the intent of reconstructing the events leading to suicide[15]. The psychological autopsy serves as a bridge between law and psychology, providing insights into the motivations, feelings, and mental health conditions of the deceased. The importance of this investigative technique is underlined by the complex interplay of factors that can lead someone to take their own life, including mental health disorders, emotional distress, and social influences [19]. A psychological autopsy involves interviews with friends, family members, and others who had meaningful contact with the individual, thereby constructing a detailed personal history [6]. This historical perspective is paramount as it helps investigators understand the various domains of the deceased's life, such as their emotional well-being, social relationships, career pressure, and any signs of mental illness [6]. The data gathered can then be reviewed in conjunction with clinical assessments and clinical diagnoses when available, thus allowing a more comprehensive view that encompasses both subjective experiences and objective facts [16]. The technique also has practical implications in improving overall public health responses to suicide [3]. By analysing common psychological and emotional patterns in cases where individuals have completed suicide, mental health professionals can identify risk factors that may be prevalent in certain demographics or communities [1]. This insight can lead to improved prevention strategies and mental health interventions,



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highlighting the role of psychological autopsies not only as forensic tools but also as instruments for social change [1]. Furthermore, there is a growing demand for psychological autopsies in legal contexts[9]. As the justice system grapples with the nuances of culpability and intent, establishing a clear understanding of a deceased individual's psychological state can help mitigate legal ambiguity[9]. Defense attorneys may implement psychological autopsy findings to advocate for reduced sentences or to argue that a defendant's mental state at the time of an offense should be taken into account[9]. Conversely, prosecutorial teams might use psychological autopsy findings to substantiate claims about an individual's predisposition to certain behaviours, further illustrating the complexities of human psychology within the legal framework [10].

Usage of Psychological Autopsy in Understanding Suicidal Deaths

Unpacking Motives and Risk Factors

In the realm of suicidal deaths, psychological autopsy plays a vital role in discerning the motives and risk factors that may have led to a tragic outcome[10]. By examining the individual's emotional and mental condition prior to their death, investigators can gain significant insights into what might have driven them to take such drastic action[10]. This understanding can be crucial for supporting those who may be struggling or at risk, emphasizing the importance of early intervention.

Recognizing Warning Signs

Psychological autopsy serves as a crucial tool in identifying warning signs and red flags that may have been overlooked during initial investigations[15]. This analysis can expose critical details about the deceased's emotional struggles, behaviour changes, or social interactions, providing actionable insights that can prevent future tragedies[11]. By recognizing patterns and signs, experts can offer support to at-risk individuals and potentially save lives[11].

Differentiating Between Suicide and Homicide

In cases where the cause of death is ambiguous, psychological autopsy can aid investigators in distinguishing between suicide and homicide[11]. By assessing the psychological context surrounding the death, forensic experts can draw informed conclusions about the individual's circumstances, further guiding the investigation[11]. This distinction is essential, as it can shift the focus of investigative efforts significantly.

Usage of Psychological Autopsy in Investigating Equivocal Deaths

Providing Context to Uncertain Deaths

For cases shrouded in uncertainty—where the cause of death is not immediately clear or where foul play is suspected—a psychological autopsy provides invaluable context[15]. It can illuminate the individual's mental state, interpersonal relationships, and any underlying conflicts or stressors that could be relevant to the case [1]. Understanding these dynamics can enrich the investigation and possibly reveal motives or circumstances that may have contributed to the death[15].

Ruling Out Homicide

In situations where investigators are considering possible homicide, psychological autopsy can help eliminate this theory by presenting a thorough analysis of the deceased's psychological condition and propensity for suicidal behaviour[15]. Establishing that the death likely resulted from the individual's own actions, rather than foul play, is crucial for focusing investigative resources effectively[15].

Spotting Unusual Circumstances

Equivocal deaths often involve peculiar circumstances or behaviours that lack easy explanations[15]. By employing a psychological autopsy, investigators can unearth any extraordinary psychological factors that might have played a role in the death, paving the way for a clearer understanding of the events that transpired[15].



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PSYCHOLOGICAL AUTOPSY: METHODOLOGY

Data Collection

Psychological autopsy process employs a multi-method approach to gather relevant data (See **TABLE 1**). This process typically involves:

- Interviews with Relatives and Friends: Engaging with individuals close to the deceased to gather qualitative insights into their thoughts, feelings, and behaviours[18].
- Review of Medical Records: Analysing healthcare documentation that might reflect the deceased's mental health history, medications, and previous treatments[18].
- Investigative Reports: Considering police reports, witness statements, and scene descriptions to gather contextual information about the circumstances surrounding the death[18].

Analytical Framework

The analysis of the collected data often applies qualitative methodologies, such as thematic analysis, to identify recurring patterns and significant variables that contributed to the individual's mental state [2]. The reconstruction of a life narrative is a key element in psychological autopsy, providing a holistic view of the deceased's experiences[15].

Psychological Autopsy: The Importance of A Holistic Approach

Conducting a psychological autopsy typically requires gathering comprehensive data through interviews with family, friends, and associates, in addition to reviewing medical records, personal journals, and other relevant documents[18]. This holistic approach offers a richer portrayal of the deceased's life and the complexities surrounding their death. It's essential to recognize that psychological autopsy does not replace conventional forensic techniques; rather, it serves as a supplementary method, enriching the overall investigative process[15]. By examining the psychological and emotional facets of a case, investigators can better determine the manner of death—whether it be suicide, homicide, or an accident—and refine the direction of the investigation[15]. Thus, psychological autopsy stands as an important tool in forensic science, bridging the gap between emotional understanding and investigative rigor[15]. When utilized appropriately, it not only aids in individual cases but also contributes to broader efforts aimed at understanding and preventing suicides and improving mental health support[11].

Practical Applications of Psychological Autopsy: An Insight

Psychological autopsy serves as a valuable tool for police investigators when dealing with equivocal deaths, helping to connect various loose ends in criminal cases[4]. Given the complexity of human behaviour and diverse social structures, its frequent application is recommended to enhance criminal investigations[4]. By reconstructing factors influencing the victim's life and circumstances, psychological autopsy can provide insights that are crucial for discerning the true causes of death. Emphasizing its importance, the integration of psychological autopsy into India's legal system is viewed as a means to further enrich and improve investigative processes in the context of equivocal deaths[4]. Case studies further exemplify the utility of psychological autopsies in elucidating the circumstances surrounding suicides. A representative case demonstrates how a psychological autopsy can reveal previously undisclosed factors contributing to an individual's suicidal behaviour [2]. In their study of a 27-year-old male who died by suicide, the investigators uncovered layers of psychological distress rooted in his personal relationships and career pressures, providing a narrative that traditional forensic investigations might have overlooked [2]. The richness of detail gained through psychological autopsy can inform not just the specifics of a given case but also contribute to broader understanding within psychological and forensic literature [2]. In a case, investigators encountered unresolved issues regarding the cause of the victim's death, including the possibility of accidental or suicidal poisoning and whether coal gas poisoning was staged[1]. Due to the lack of evidence beyond a reasonable doubt, the court dismissed the criminal case against the accused, emphasizing the insufficiency of mere suspicion for conviction [1]. The court noted that the case was fraught with improbabilities[1]. It suggests that employing a psychological autopsy could have aided investigators in clarifying these uncertainties by reconstructing various factors related to the death, highlighting the method's significance in equivocal cases[1].



Souvik Dhar *et al.*,**A Case Study of a Young Male**

In the case, psychologists conducted a psychological autopsy on a 27-year-old male who had died by suicide [2]. Through interviews with family and friends, it was discovered that the individual had faced significant struggles with depression and recent job loss [2]. This insight provided clarity to the circumstances of his death, painting a fuller picture of his life that could help guide future interventions [2].

Understanding Patterns of Mass Suicide

Researchers explored the psychological autopsy framework in the context of mass suicides, demonstrating that societal pressures and shared beliefs can contribute to collective suicidal behaviour [12]. By analysing these situations, mental health authorities can devise community-centric intervention strategies [12].

Burari Deaths

The Burari deaths refer to the tragic incident in July 2018, where eleven members of the family were found dead in their home in Burari, Delhi [12]. Initially ruled as a mass suicide, subsequent investigations revealed complex psychological factors at play, prompting discussions about the mental health of the family [12]. A psychological autopsy was conducted to understand the circumstances leading to this event. This process involves a comprehensive analysis of the deceased's psychological state through interviews with family and friends, examination of personal writings, and review of medical and social histories [12]. In the Burari case, the findings highlighted the influence of familial pressures, shared beliefs, and possible mental illness, underscoring the importance of mental health awareness and interventions in preventing such tragedies [12].

Psychological Autopsy: Recent Trends

In recent years, the application of psychological autopsy has seen a transformation influenced by various trends, including:

- **Increasing Suicide Rates**

The World Health Organization (WHO) reported that suicide is a significant global health issue, with nearly 800,000 individuals dying by suicide every year [7]. As mental health problems gain visibility, the demand for comprehensive investigations into suicide has increased, propelling the relevance of psychological autopsy as a method to unravel the complex layers leading to such tragic outcomes [11].

- **Advancements in Research Methodologies**

With the advent of advanced research methodologies and data analysis tools, researchers are better equipped to perform psychological autopsies. For instance, predictive modelling and machine learning techniques are being introduced to analyse large datasets, offering more efficient ways to identify risk factors associated [5]. This evolution allows for a deeper understanding of trends and markers that could help in timely interventions.

- **Integration of Multidisciplinary Approaches**

The multifaceted nature of psychological autopsy has led to collaborative efforts among various disciplines, including psychology, psychiatry, law enforcement, and forensic science [13]. This collaborative framework not only enriches the data collection process but also allows for a diverse range of perspectives in analysing the psychological factors associated with suicide [13].

- **Legal Implications and Forensic Applications**

Legal systems increasingly recognize the importance of psychological autopsies in court proceedings. The insights gathered through this method can significantly impact jury decisions and legal outcomes, especially in cases where the intent behind a death is questioned [23]. Expert testimony based on psychological autopsy findings is becoming commonplace in legal contexts, underscoring its growing importance.



**Souvik Dhar et al.,****• Impact of Technology**

The increasing accessibility of digital data and online footprints offers new avenues for psychological autopsies. Analysing social media activities, online interactions, and digital communications can provide additional context about an individual's mental state leading up to death [8]. Consequently, technology plays a pivotal role in modernizing the investigative process and opening up potential areas for inquiry that were previously inaccessible [8]. There are emerging trends in the application of psychological autopsies in the context of larger public health crises, such as the increasing prevalence of mass suicides in certain cultural or socio-economic settings. Research has indicated an evolving psychosocial landscape that contributes to collective patterns of despair. Researchers suggest that understanding these patterns through psychosocial autopsy can guide intervention strategies tailored to specific populations, aligning public health efforts with empirical evidence derived from thorough investigations of individual cases within a larger framework [14]. Another crucial aspect of psychological autopsies relates to the ethical considerations involved in their execution. Conducting such in-depth inquiries into someone's life posthumously requires sensitivity, respect, and a thorough understanding of ethical standards in psychological practice [11]. The importance of maintaining confidentiality and dignity for the deceased cannot be overstated, as the ramifications of open investigations can affect bereaved families and communities [11]. Mastering the art of conducting psychological autopsies thus not only hinges on methodological rigor but also on an ethical commitment to those whose stories are being uncovered [20]. The advancements in forensic technology and methodologies have also paved the way for improved psychological autopsy practices [14]. For instance, digital resources and data analysis techniques can enhance the depth and accuracy of information gathering, enabling investigators to build more nuanced profiles of individuals [14]. These technical enhancements have proven particularly useful in exploring online behaviours, social media interactions, and other digital footprints that can yield insights into the mental states preceding a suicide. These modern techniques exemplify a convergence of psychology and technology, emphasizing that psychological autopsies can evolve in response to societal changes [14]. Thus, psychological autopsy has emerged as a vital instrument in the forensic investigation of suicides, moving beyond traditional evidence-focused approaches to encompass the psychological dimensions of such tragic events. The compelling need to understand the human psyche in the context of suicide highlights the strength of this method in illuminating the often-circumstantial nature of these deaths. As societal awareness of mental health continues to evolve and grow in importance, integrating psychological autopsies will likely shape future forensic investigations, offering richer narratives that advocate for change in how suicide is approached within the fields of law, psychology, and public health. The development of this field will be facilitated by ongoing research, refinements in methodology, and an ethical commitment to preserving the dignity of those whose stories are shared through the practice of psychological autopsy.

Future of Psychological Autopsy: Integration of Artificial Intelligence And Machine Learning In Forensic Science

The integration of Artificial Intelligence (AI) and Machine Learning (ML) in forensic science has transformed investigations by bringing new levels of speed, accuracy, and efficiency. In recent years, AI has been developed for a range of forensic applications, including fingerprint and facial recognition, DNA analysis, and crime scene reconstruction [5]. The integration of AI algorithms and forensic genetics has the potential to enhance the accuracy, efficiency, and reliability of forensic investigations, ultimately leading to better outcomes in solving crimes and identifying perpetrators [17]. With rapid technological progress, the use of AI in forensics presents significant opportunities. Specifically, AI technology has tried to overcome the human subjective bias limitations and traditional approach of forensic sciences [6], thereby providing more accurate results. AI has lately been applied in forensics to recognise fingerprint patterns [6]. Traditionally fingerprints were analysed using the ink and paper method, which due to its reliance on human subjectivity, caused significant margins for error. Integration of AI has led to sophisticated machine learning algorithms sieve through and interpret large data sets with accuracy and recognise unique patterns [21]. This helps in identification of similarities and anomalies within fingerprints, aiding forensic investigators in solving complex cases [21]. Natural Language Processing (NLP) is another area where integration of AI in forensic linguistics has made significant strides. Forensic linguistics employs linguistic interpretation processes as evidence in legal cases [22]. NLP not only aids in simple analysis of textual evidence, but helps in identification of patterns by analysing tone, pitch, sentiments, idiolects [22] of the writer that might give insights into their thought





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process or intent behind their actions. DNA sequencing has been considered as the keystone of forensic science. It has emerged as another key area where use of AI technologies in forensic labs is assisting in faster and more reliable sequencing, even in cases where samples couldn't be preserved properly. Faster processing of DNA evidence can help in speedier disposal of cases. These advancements also help in building accurate profiles of suspects or accused linked to crime scenes [17]. Crime prevention is one of the top priorities of governments worldwide and they take necessary actions to bring down crime rates [3]. Attempting to predict crime is neither manually possible, and even if done, such analysis is not very reliable. AI and ML, analyse the data sets collected by the police departments to extract patterns and predict future events [3]. As an example, a dataset was used to examine crime data from Vancouver, Canada in the last fifteen years to identify areas which were most likely to experience crime [9]. The accuracy rate of such predictions ranged between 39 to 44 percent [9]. Thus, the integration of AI with ML will make analysis with complex psychological data more enhanced; its algorithms will process tons of information extracted from patients' medical records, the quantity of activity on their social media, and personal communication messages to indicate patterns as well as factors that associate risks with mental health issues, including suicides. Its ability to predict behaviour will facilitate the determination of how humans behave through ML, therefore helping the professionals accurately deduce psychological states lying deep within their minds. This technological approach will assess more comprehensively, in turn allowing interventions in real time and with more sound mental health support. Generally speaking, AI and ML enhance effectiveness and accuracy with regard to psychological autopsies that improve mental health outcomes.

Psychological Autopsy: Challenges In Conducting

While the applications of psychological autopsy are on the rise, several challenges remain:

- **Subjectivity and Interpretative Bias**

The qualitative nature of data collected in psychological autopsies can be influenced by biases from the interviewers and respondents. Variations in perception, memory recall issues, and emotional responses may all contribute to a less objective analysis. It can pose difficulties, particularly in forensic settings where factual precision is paramount [10]

- **Ethical and Privacy Concerns**

The conduct of psychological autopsies often delves into personal histories and sensitive information. This raises substantial ethical concerns regarding consent and the potential re-traumatization of family members during the interview process. The approach must be carefully managed to uphold the dignity and emotional well-being of those involved [20]

- **Interdisciplinary Coordination**

While collaboration across disciplines can enhance the findings of psychological autopsies, it can also lead to complications in communication and integration of diverse methodologies. Establishing effective channels for collaboration is crucial in overcoming these hurdles and ensuring comprehensive analysis [14].

CONCLUSION

The psychological autopsy as a forensic tool holds significant promise for advancing the understanding of suicide and mental health-related deaths in contemporary society. As suicide rates climb and the societal focus on mental health intensifies, the utility of this technique in forensic investigations becomes even more critical. Continued interdisciplinary collaboration, the integration of technology, and awareness of ethical considerations will enhance its application and effectiveness. The use of AI and ML in forensic science is promising to strengthen and bolster the criminal justice system. However, data biases and quality may impact the AI driven conclusions. Adherence to principles of fairness and transparency in the field of forensic sciences can lead to harnessing the potentials of AI to the maximum possible extent. Through rigorous data collection, qualitative analysis and usage of technology like AI and ML, psychological autopsy will play a central role in elucidating the often-mysterious complexities of human behaviour leading up to death. As such, this approach should be regarded not only as a tool for investigation but as a catalyst for broader societal change concerning mental health awareness, preventive strategies, and support for





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vulnerable populations. Further research into systematizing methodologies will fortify its place in forensic science, ultimately fostering a deeper understanding of the tragic phenomenon of suicide and saving lives in the process.

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**Souvik Dhar et al.,**23. Well, D. (2012). Testifying in court as a forensic expert. *NIJ Journal*, 269.**Table.1: Psychological Autopsy Process**

Step	Description
1. Case Selection	Choose cases that warrant a psychological autopsy based on their circumstances (e.g., suicide, unexplained deaths).
2. Data Collection	Gather data from identified sources, ensuring to respect privacy and confidentiality. This includes interviews and reviewing documents.
3. Timeline Creation	Construct a timeline of significant events in the life of the deceased leading up to death, including life stressors, mental health history, and social interactions.
4. Analysis	Analyse the collected data to identify patterns of behaviour, unresolved conflicts, and psychological conditions. Look for indicators of mental health issues or situational triggers.
5. Report	Compile findings into a comprehensive report that summarizes insights, potential causes of death, and the individual's psychological state prior to death. Offer recommendations if appropriate.





Assessing the Therapeutic Potential of Balyadi Lepa and Kanji: A Pharmaco Analytic Approach

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ABSTRACT

In the modern day, ayurvedic medicine therapy is thought to be the most effective, the primary source of effective ayurvedic medication is Herbo-mineral pharmaceuticals. Skin diseases are prevalent in all age groups of people, and the most effective treatment for them is local application, which is simple to use and effectively treats the disease. This article is based on the balayadi lepachurna with kanji preparation of the to local application of the shwitra. A shwitra is include twakavikar in kustharoga. A sthanik chikitsa should be done in shwitra. This study investigates the pharmacological properties and clinical efficacy of two traditional remedies, Balyadilepa and Kanji. Balyadilepa is a topical application used in Ayurvedic medicine, while Kanji is a fermented rice-based drink. This analysis aims to understand their potential therapeutic benefits, mechanisms of action, and safety profiles.

Keywords: Sthanik chikitsa, Churna Kalpana, Balyadilepakanzi, Twakavikar, Shwitra and herbo-minaral

INTRODUCTION

The skin disease is most common in present era, the shwitra will be considered on among the skin twakavikar, all acharya will be considered shwitra is kushtaroga, mainly kushtaroga treatment have mentioned local application. it



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is effective source of herbo mineral medicine. The word of lepa is derived from lepan, in sushruta Samhita lepa will be classified in 3 types The balyadilepa described in yogratnakarkushta chikitsa adhayay shloka 5 That allmost Dravya is action on kushtghana, krimighan kandughanash witrakar as wedjanana dahshamak Ranjana etc. Kanji used in the preparation of lepa and form to semisolid to easy application

MATERIAL AND METHOD

Balyadilepa will be prepared in churna Kalpna and kanziprepared in Sandhan kalpana. Pharmaceutical procedure and pharmacanalytic procedure are divided in different stage

1. shodhan of ingredient of balyadi lepa churna
2. balyadi lepa churna preparation
3. kanzi preparation
4. analysis of balyadilepa churna
5. analysis of kanzi

shodhan of balyadilepachurna [ingredient]**Bhallatak shodhan**

- Pratham shodhan
Firstofall, take bhallataka fruit and fine powder of red brick, and fill in a cotton bag and rub in medium pressure. When brick powder absorbs the oil of bhallataka fruit oil means when the skin of bhallataka fruit separate from it then its clean in warm water
- Dwityashodhan
Make two pieces of bhallataka fruit, and fill the coconut water in a vessel and dip the bhallataka fruits in the vessels and boiled 2 hours. This processmake pure bhallataka fruits

Precution of sodhan

Use coconut oil onface hand and expose area, and wear gloves, face shield and mask properly. Bhallatak fruit break very carefully. And mixed with red brick water its rotate car

balyadilepachurn a preparation

- Tack all ingredient of balyadilepa and make fine powder,distrigatour, micropulverizer, shifter used for powder macking
- Fine powder passed 80#
- After that powder is homogenous mixed with help of mass mixture
- Fine powder of balyadilepa packed air tight container.

kanzi preparation

- Tack the shali rice and boiled in clay 1.5 kg rice will be tacken and add to 15 liters water and boiled
- Rice will be half ripen and add nimbu
- Filled in clay pot and vessels mouth packedair tight container
- After 15 days examination of solution
- Filtter with cotton cloth
- Keep it glass bottle of preparation

PREACUATION TACKEN DURING PROCESS

Take good quality rice and clean it before using. Take rice and water in classical ratio.Use air tight clay pot for fermentation of rice.Check smell, flame test for surety of good kanzi



**Hemangini Malivad et al.,****Stage 4 analysis of balayadi lepachurna****DRUG ANALYSIS****THIN LAYER CHROMATOGRAPHY**

EXTRACT; methanol soluble

Solvent System: petroleum ether, diethyl ether ,acetic acid

Stage 5: analysis of kanzi**DISCUSSION**

The procedure works best for making Balyadi Lepa Powder. Madhur, Katu, Tikta, and Kashaya rasa make up Balyadi Lepa. snighdhaguna, mradu, ruksha, tikshna, guru, and lagu. Sheet virya with Ushna. katuvipaka and madhur, Kaphavatashamak, pittavardhak, vatapittashamak, kaphapittahar, and kaphapittashamak. Amaltas, vaybidanga, and nimba are plants that contain tenin, which is used to color skin. Shodhana is done before to lepachurna preparation. Powder needs to travel through 80 # For the goal of uniform mixing, mass mixture is employed. Lepa, or soft pastel, is ready to use. Prepration of lepa (semisolid form) has a brief shelf life. Thus, we made the lepachurna and stored it beforehand. 79% of the prepared churna is fine powder, as evidenced by our balyadilepa blending well with the kanji. In the thin layer chromatography of balyadilepachurna maximum rf value will be found o.it composition Kaempferol, a natural flavonoid, influences melanin pigmentation through multiple mechanisms. It regulates tyrosinase activity, activates pathways like MITF, and reduces oxidative stress via antioxidant properties. Kaempferol also enhances melanocyte differentiation and modulates inflammation, impacting pigmentation. Quercetin, a plant-based flavonoid, impacts melanin pigmentation by inhibiting tyrosinase activity, reducing melanin production, and downregulating MITF, a key melanogenesis regulator. Its antioxidant and anti-inflammatory properties protect melanocytes from oxidative damage and inflammation, further modulating pigmentation. Sitosterol, a plant-derived phytosterol, may influence melanin pigmentation through its anti-inflammatory and antioxidant properties, which stabilize melanocyte activity and protect against oxidative damage. It may also modulate signaling pathways like Wnt/ β -catenin and support melanocyte function via improved skin barrier health phenolic compounds, plant-derived metabolites, influence melanin pigmentation by activating tyrosinase, modulating signaling pathways like MITF and cAMP/PKA, and providing antioxidant protection to melanocytes. Compounds such as caffeic acid, ferulic acid, and chlorogenic acid stimulate melanin synthesis, while others like EGCG support melanocyte proliferation and UV-induced melanogenesis. Flavonoids, polyphenolic compounds from plants, can enhance melanin pigmentation by activating tyrosinase, upregulating MITF, and protecting melanocytes through antioxidant activity. Compounds like kaempferol, quercetin, and epicatechin stimulate melanogenesis, while flavonoids such as luteolin promote melanocyte proliferation. They also enhance UV-induced pigmentation by protecting against oxidative damage. These properties make flavonoids valuable in skincare for boosting pigmentation and in medical research for treating hypo pigmentation disorders like vitiligo. Once made, lepa (paste) is simple to apply to diseased areas. Alepachurna's shelf life is two years. Kanzi to be used as a powdered balyadilepa.

CONCLUSION

The foundation of Balyadi Lepa is Yogaratanakara chikitsa adhayaya. External administration of therapeutic action without adverse consequences. Analytical investigations revealed that the medication is microbe-free and falls within the accepted guidelines for topically applied dosages. The fusion procedure works best while preparing Balyadilepa. The powder of balyadilepachurna is fine. It creates an easily applicable "LEPA" when combined with the soft kanji paste. Lepachurna has a two-year shelf life, whereas mass-prepared lepa or semisolid has a shorter one. In order to prepare and store lepachurna before using it to prepare lepa or semi-solid mass.





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Table 1 ingredients of balyadilepa

Ingredient	Botanical name	Action	Quantity taken
Vindag	Embeliaribes	Kapha vatashamak,kushthghana ,varnya	300gm
Chitrak	Plumbago zeylanica	Kapha,vatashamak,pittavardhak	300gm
Bhallatak	Semicarpus anacardium	Kapha,vatashamak,pittavardhak	300gm
Dantimoola	Baliospermummontenum	Kaphapittahara	300gm
Amaltas	Cassia fistula	Vatapittashamak	300gm
Nimba	Azadirachta indica	Kaphapittashamak	300gm
Gandhak	Sulpher	Twakavikar	300gm

Table 2 Result obtain of balyadilepa

Parameter	Result
Raw material tackin in [kg]	2.1 kg
Received quantity in [kg]	1.75kg
Loss during prepration	0.35kg

Table 3 Oraganoleptic character

1	Colour	Brown
2	Odour	Odourless
3	Taste	Bitter
4	Consistency	Solid [powder]





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Table 4 Physiochemical parameters

Sr no	Sample parameter	Balayadi lepavalvue
1	Loss of dryness at	1.7248
2	Total ash value	10.4543
3	Acid insoluble ash valvue	41.95
4	Water soluble Extractive	8.6
5	Alcohol soluble extractive	31.4
6	Ph value	7.2
7	Particle size distribution [mess analysis]	
	10-20	100%
	20-40	90%
	60-80	58%
	80	43%
	120	27%

Table 5 composition of rf value

Rf value[max]	Composition
0.171	Kaempferal
0.342	Quercetin
0.485	Sitosterol

Table 6 Organoleptic and physiochemical character

Colour	Milky white
Odour	Amlagandhi
Taste	Amla [sour]
Sound	Hissing
Ph	4
Flam taste	Positive
Specific gravity	1.0195

Table 7 chemical composition of rf value

Rf [max]	Composition
0.043	Phenolic compound
0.408	Flavonoid





Figure 1 ashudhabhallatak



Figure 2 shodhitbhallatk



Figure 3 RAW MATERIALS OF BALYADI LEPA CHURNA



Figure 4 half boiled rice



Figure 5 added lemon piece



Figure 6 kept on fermentation

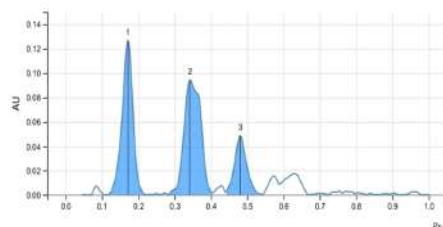




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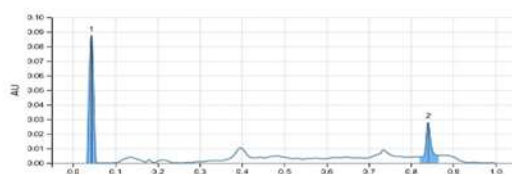


Figure 7 filtration



Peak #	Start		Max		End		Area	
	R _F	H	R _F	H	R _F	H	A	%
1	0.115	0.0000	0.171	0.1267	0.222	0.0000	0.00444	35.74
2	0.283	0.0002	0.342	0.0943	0.403	0.0017	0.00511	44.56
3	0.440	0.0024	0.481	0.0488	0.528	0.0013	0.00190	15.59

Figure 8 Chart 1hptlc@254nm



Peak #	Start		Max		End		Area	
	R _F	H	R _F	H	R _F	H	A	%
1	0.033	0.0000	0.043	0.0874	0.056	0.0000	0.00102	69.00
2	0.821	0.0041	0.840	0.0279	0.865	0.0052	0.00046	31.00

Figure 9 Chart 2 hptlc@366nm





Ergonomic Factor based Analysis on Characteristics of Quality Work Life among Office Workers

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ABSTRACT

The safety and health of the individuals can be affected by the quality of work life. Different financial and non-financial factors are the key aspect to analyze the performance of the employees in which the workplace facilities and convenience are the important considerations particularly for the office related works. This paper presents the analysis of quality of work life for different office workers and investigate its organization with lower back pain (LBP) and neck pain (NP). This cross-sectional analysis was conducted among office employees working in a single organization. Office workers who are with or without LBP and NP were considered and made a survey about each participant and collected the data over a 4-month period with accordance to the measurement of lighting intensity and physical fitness. Furthermore, multi output regression is proposed for the significant analysis of the risk factors and the relationship between the dependent and independent variables that are associated with NP and LBP were analyzed. In conclusion, results are indicating the nature of hazards that affects NP and LBP in the workplace for the office workers. The analysis shows that the need for improvement in ergonomic factors for preventing the LBP and NP for quality of work life among office workers.

Keywords: Lower Back Pain, Neck Pain, Physical Fitness, Office Workers, Ergonomics Factors

INTRODUCTION

Nowadays, an important subject of science is considered to be the Ergonomics that is mainly centered towards response and behavior of humans with respect to their movement, sitting, and standing. The ergonomics is



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contemplated as a human way of thinking and philosophical concept. This methodology is applied in different areas such as transportation, entertainment facilities in home, education, workplace, public, aviation, and sports [1] [2]. Ergonomics is the scientific concept that indulged with common sense but the application and utilization will not be an easy way as it needs to be developed and used by complex peoples with various perspectives that makes system more complicated for designing based on the accommodation. Some of the workplace challenges such as structural design, institutional obstacles, and arrangements with errors can lead to certain circumstances where safety and health of the employees become questionable [3] [4]. Musculoskeletal Disorders (MSDs) is one of the most common problems occurred in office workers. The MSDs are much related to joints, nerves, muscles, and tendons which can affect various regions of bodies such as upper limbs, back, and neck. The main contributing factor in job such as reduced quality of life, increase in work-related injuries, presentism, absenteeism, increase in medical expenses, and change of occupation is considered to be the work-related musculoskeletal disorders [25] [26]. In various companies and occupations, office workers spent more hours in from a computer system and also spending their office times in seated positions. Use of computer systems has multiplied in workplaces, that is related to MSDs-associated signs with an incidence fee of greater than 50%, specially with inside the top extremities and decrease back. Also, pain/soreness due to MSDs, with inside the neck, shoulders, and decrease back, are not unusual place amongst work place employees because of the time spent in a sitting position. Worldwide, MSDs are great and feature each socioeconomic and private consequences [27].

The practitioners of the human elements and ergonomics (HF/E) field have evolved a chain of theories, principles, and techniques to assess human-device machine overall performance. From the HF/E aspect, techniques of comparing human paintings within the machine fall into the subsequent categories: Physical techniques, psychophysiological techniques, behavioral-cognitive techniques, crew techniques, environmental techniques, and macro-ergonomic techniques. The impact of ergonomic evaluation among the office workers who are concurrently sitting in from of computers for long time [28]. Office staff perform varied activities, similar to typing, writing, and reading which will be joined with prolonged static and awkward postures, repetitive movements, and high mental workloads. workplace personnel as an enormous cluster of staff are exposed to MSDs. As explicit above, MSDs are complex work-related problems [29].

Therefore, this study was done to analyze MSDs and its associated factors among Iranian office workers. The ultimate goals of ergonomics are enhancing the overall performance of the systems and well-being which can achieved through the interventions of ergonomics. The primitive definition is given for intervention which is to meant to be purposeful action done by the human agent for creating a change [5]. The implementation of these interventions are made at macro-ergonomics and micro-ergonomics levels in industries, field or laboratory, organizations, and workplaces. Some of the occupational interventions of ergonomics in the workplace environment are accomplished using bottom-up, middle-out, or top-down strategies. Various organization work strategies and interventions have been proposed for improving the health and productivity, reduce or prevent work-related disorders, and quality of work-life (QWL) [6] [7]. Figure 1 shows the human and ergonomics factors. Neck Pain (NP) and Lower Back Pain (LBP) is a frequent and chronic condition of global wide. The risk factors indulged with NP and LBP are multifactorial which broadly categorized into work-related factors (e.g: job control, computer hours per day at work, physical demand at work) and individual factors (e.g: psychological distress and health behavior) [8]. Most of studies have mainly focused on the associations between the NP, LBP, and other risk factors rather than including work-related and individual factors. Moreover, when the physical-risk factors such as endurance/strength, range of motion, and shoulder/neck muscle were measured, it is not specific for the office workers as the sample sizes are smaller [9] [10]. Quality Work Life (QWL) is defined to be the unfavorableness or favorableness of the work environment for the employees. Various factors can affect the broad concept of QWL and different characteristics such as task identity, autonomy, feedback, skill variety, and task significance are affecting the QWL factors. The influential factors of QWL is mainly divided into two categories of intrinsic and extrinsic. Some of the important intrinsic factors such as skill variety, social environment, and nature of work is used for determining QWL and for extrinsic factors are working condition, working hours, and monetary payments [11] [12]. Warr et al. [13] highlighted on perceived intrinsic job characteristics, happiness, motivation, participation, high order strength, self-rated anxiety, and life satisfaction are the important factors used for shaping QWL. Nanjundeswaraswamy and Swamy [14]



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reported various components in their study for QWL and stated that reward systems, career advancements, participation in decision making, job security, and training are main components for the QWL in manufacturing industries.

RELATED WORKS

Stead and Lin [36] discussed that ergonomics in the field of human computer interaction. Authors defined that ergonomics can help to design improvement by analyzing the measurement. The ergonomics is the scientific discipline that is the concept of understanding and interacting among computer systems and humans. Furthermore, the profession that applies data, theoretical principles, and methods for optimizing for human use by proper design to obtain overall performance. Chan [37] indicated that the variables of quality, productivity, and safety is improved using the ergonomics. Authors have studied about the work design in practice for number of cases that compiled in various industries. The case studies based on the ergonomics outlines the situations held in various industries. Hafize Keser and Safak Bayir [38] made a cohort of study for determining the evaluation of information and communication technologies coordinator teacher trainers (ICT-CTT's) in the organization in the working environment with computers when considering the ergonomics. Authors shown the responsibility such as guiding, counselling, and training the ICT coordinators and teachers for the students by planning, evaluating, managing information technologies and authors considered nine-subsections such as selection of chair, keyboard and mouse, lighting, temperature, humidity, selection and organization of computer desk, noise, training and information, and ventilation. Hopkins [29] and Le Coze [30] discussed the human factors or ergonomics (HFE) which gives the academic discipline and practice for the professionals that also offers the knowledge and theory for 50 years of experience in various complex sectors such as rail, aviation, petro-chemical, and defense that maintains a low incident rates despites of having risky environments. Carroll and Rudolph [31] have discussed the healthcare for dynamic, interdependent, complex, managing uncertainty, chronic underfunding, and incomplete data. Du et al. [32] discussed human ergonomics factors and its useful approaches in which three fundamental characteristics are considered about the traditional QI efforts and safety by being design driven, taking a systems approach, and focusing on dual outcomes. Jarvelin and Rasanen [33] have applied the HFE and the professional practice that should be shifted the significant changes for modern working life that creating a new demands and HFE has the opportunities both as an educational requirements and discipline.

Cuenca and Aslandies [34] analyzed the issues of ongoing challenges of professional identity of HFE. The authors additionally advise that the IEA may want to offer assist for the justification of expert stage HFE schooling programs. The Swedish HFE community advanced a method to actively sell the subject and undertook a multifaceted technique to have interaction with the enterprise and the overall public on a number of topical areas. Brown and Legg [35] discussed Since its origin HFE education has long-faced several challenges. Few dedicated HFE courses were existing or programs and these were sometimes at postgraduate level, building on students' previous degrees in an exceedingly wide selection of topics love engineering, technology, psychology, design, health, nursing, physiotherapy, medication and management. HFE courses or programs usually had variable emphases. The HFE course content commonly trusted the main target of the tutorial programs (e.g. in Colleges, Institutes, colleges or Departments of Health or Engineering or style or Management) during which they were placed at intervals universities. This focus usually meant that HFE courses were unable to hide the total vary of areas encompassed by HFE - physical, psychological feature and systems applied science. Recently courses have enclosed coverage of socio technical systems, organizational, community or environmental ergonomics and property. Ellis and Pompili [15] mentioned that for various groups the components of QWL can be varied and the authors conducted a study for the workers in hospital and listed various factors such as resident aggression, inability to deliver quality of care, shift work, professional isolation, poor relationships, lack of opportunity, learning new skills, lack of recognition, poor working environments, workload, balance of work and family, and role conflict are the main components of QWL. Mirvis and Lawler [16] introduced some factors such as safe work environment, equal employment opportunities, progress, and fair wages as the important categories of QWL by investigating the corporation service company.



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Rethinam and Ismail [17] found well-being, balance work and life, competence development, and health as the components by conducting the study among the professional working in information technology company. Nazari and Dashti [18] investigated that the improvement in QWL will leads to desirable outcomes which enhances effectiveness, efficiency, lower occupational accident rate, organizational productivity, and job satisfaction. Uysal et al. [29] showed that the analysis on some studies indicate that improving a good level of QWL will reduce the work-related absences and employee complaints. Ashrafi et al. [20] and Jafari et al. [21] made a study that undesirable QWL will leads employees to affect with mental disorders, burnout symptoms, and increase turnover rate. Ashrafi et al. [20] evaluated the QWL effect on outputs such as emotional exhaustion, depersonalization, and personal accomplishment might be mediated by burnout. The QWL effect on psychological well-being is demonstrated by Salehi et al. [22].

MATERIALS AND METHODS

Participants Recruitment

In this research, a 4months' continuous study is designed for the office workers for a particular organization. The sample-size of the data is calculated based on the follow-up of the study for 4 months for estimating the ergonomics factors such as LBP and NP. For this calculation, one sided test with null hypothesis of incidence rate is estimated as the sample size. The LBP and NP incidence rate for 2-months among the university workers and it is reported to be 45%. The value of incidence rate of LBP and NP is tested for $\alpha_0 = 0.45$ at the level of significance as 5% with the power of 92%. The anticipated incidence rate is 50% which is $\alpha_a = 0.50$. Overall 180 office workers are required as a minimum sample size. During the follow-up, 20% of required sample size is increased for allowing dropout and withdrawal of participants. Figure 2 shows the process of study for this research. Name list of the office workers for all units is provided by the organization and included in the computer program. This process of group screening is done using simple random sampling and firstly invited the participants for the interview and then accepted for this study. The eligibility of the participants who are included in this study are considered to be full-time office workers who are working for at least 5 hours per day with the computer and should be minimum of 6-month experience in this particular office for the same position and interested to join in this participation. If the participants having LBP and NP at a severe level, having an history of these problems during one month or some medical functions such as lumbar spine, thoracic, degenerative disc disease, and tumors, and also prolonged absence or being pregnant, they are excluded from this study. Finally, the follow-up is considered for a total of 182 office workers and formed the final sample size. In this study, NP and LBP are defined as the pain that has experienced in the spine area, lumbar vertebrate to gluteal folds or buttocks, or between the prominences of lumbosacral vertebral. Ethical approval is obtained from the organization for this study and participants were informed about the consent before participating in this study.

Demographic and Professional Information of Participants

Professional and demographic information such as work experience, age, weight, height, body mass index (BMI), gender, marital status, daily and weekly working hours are collected using the self-administered questionnaire as given in Table 1.

Quality of Work Life

For measuring the QWL, Walton's 35-item tool is used which is considered by several researchers for their study in different professional settings. Moreover, eight subscales are measured by designing the questionnaire as given in Table 1.

- **Adequate and Fair Compensation (AFC)**

AFC defined as the proportionality of pay and equal pay for equal work with staff and social criteria as well as different works. Based on the quality and quantity of work performed by the workers, employees are preferred to be paid in a lawful manner.



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- **Health and Safe Work Environment (HSE)**
HSE refers to mentally and physically safe working circumstances along with the reasonable working hours. The work environment preferred to employees are comfortable, safe, and pleasant environment that should free from hazardous agent.
- **Development of Human Capacities (DHC)**
DHC refers that job opportunities are created by companies for acquiring, applying knowledge and skills, and learning. Employees are preferring the jobs with higher levels of participation and autonomy. Such kind of job can improve attenuate work stress and job satisfaction.
- **Security and Growth (SGr)**
This subscale assesses some factors such as future ambiguity, type of contract, and opportunities for promotion and growth within the organization.
- **Social Integration (Scl)**
Scl refers that the company creates a pleasant work environment and atmosphere for reinforcing the sense of employees that they belong to this organization and they have given a vital importance.
- **Constitutionalism (Con)**
Con refers that the expression of freedom without having any fear towards the reaction of higher officials and rule of law for the domination of humans.
- **Total Life Space (TLS)**
TLS refers that the balance between the work-life and other aspects for the employee's life that includes family and leisure.
- **Social Relevance (ScR)**
ScR refers social responsibilities perceived by the employees in the organization, sense of responsibility towards the environment and rules governing the society respected by the organizations manger.

Collection of Data

The screening data and baseline measures are collected by conducting interviews face-to-face with the structured questions based on the questionnaire given in Table 1. The questionnaire part is divided into four sections and these are, section 1 collected the demographic characteristics such gender, age, and work experience, first or second job. Section 2 collected the information regarding the history of trauma, health status, chronic diseases, body mass index (BMI), and congenital disease. Section 3 is considered the evaluation of psychological stress. Section 4 enquired the behavior and characteristics of work such as back-pain preventive behavior, frequent break from sitting, suitability of workstations, and daily duration of sitting. The assessment of preventive behavior is considered based on the response from the office workers for the given questions such as awkward postures, exercise, lifting, movements, and prolonged sitting and the scores are obtained based on two classes and these are good and poor. The assessment of workstation suitability is considered based on their dimensions such as height, width, and depth of the table and seat, breadth and width of the workspace, and lighting intensity. The characteristics of each workstation is classified into inappropriate or appropriate. The physical fitness of the subjects is assessed based on the Physical Fitness Committee Test. The handgrip strength is measured using the Grip dynamometry, the strength of back and leg is measured using back-leg dynamometer, and the back muscle flexibility is measured using the back flexion-extension dynamometer. The Lutron LX-105 is used for measuring the light intensity at the office. The incidence rate of NP and LBP is calculated for the 1-month, 2-month, 3-month, and 4-month follow-up periods. The collected incidence rate is calculated for 4-months.

Analysis of Collected Data

The Epi-info version 7.2 is used for recording the collected data in Windows 10 using the method known as double data entry and STATA version 15.1 is used for the analysis. The characteristics of office and worker is described using the descriptive statistics such as mean, standard deviation, and percentage. The incidence of NP and LBP is estimated for every 1-month to the 4-month follow-up. The collected incidence rate of NP and LBP is calculated as per given eqn. 1.





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$$LBP \text{ (or) } NP = \frac{\text{Total Number of New Cases of (NP or LBP) at 1-month or 2-month or 3-month or 4-month period} \times 100}{180} \quad (1)$$

The associations between NP or LBP and mentioned study factors is analyzed using the t-test and multi output regression. The potential confounding factors such as age, work experience, and gender are included in the multi-output regression analysis and the factors which is $p < 0.2$ is included in the univariate analysis. We set $p < 0.05$ for the statistical significance and presented the risk factors by using the Relative Risk (RR) and having confidence interval (CI) of 95% for adjusted RR (RR_{Ad}). Table 2 shows the reliable variables used for this study of ergonomics for office workers.

EXPERIMENTAL RESULT ANALYSIS

Health Status and Personal Factors

From total 180 office workers, almost 78.2% of the staffs are females and the mean age for them is 34.7 ± 9.3 i.e., maximum=52 and minimum =25. The work experience mean is measured to be 13.2 ± 12.3 years i.e., minimum = 0.8 and maximum=25.5. Mostly, 41.3% is having work experience of 1-5 years, 18.4% is having 16-20 years, and 12.6% is having 21-25 years of work experience. Considering the educational background, 73.4% of workers having bachelor degree and 26.6% is having master's degree. When considering the psychological stress, 65.4% of office workers is having normal stress and 34.6% of workers is having high stress category. Almost 80.5% workers are not doing regular exercises for atleast 30 minutes and the back-pain prevention behavior is considered as poor in 22.6%, good in 10.7%, and fair in 66.7%.

Environmental Factors of Work

Majority of the offices are not considering the light intensities for the standard condition to be followed by each organization. The actual condition to be followed is 400 to 500 lx which is about minimum of 110 lx and minimum of 823lx. When considering the office chairs, 94% is having backrest, 44.5% is having flexible up-down, 76.5% is revolvable, 67.6% is inappropriate of height and width of the seats. Furthermore, the measurement of table dimensions shows that 65.4% and 63.6% are inappropriate of height and width. While considering the workspace, the width is 66.7% and 76.4% of depth which is inappropriate.

Incidence of NP and LBP

Based on the data collected from follow-up questionnaire, Table 3 shows that the incidence rate of NP which is having 58.6% and LBP is 53.4% at 2 months for 98 cases. The collected incidence rate of NP is 89.5% and LBP is 91.6% at 4 months and increased as 146 cases. All cases are work-related NP and LBP. The major reason for cause reported for NP and LBP is the prolong work at the computer in different positions. Overall 86 cases are reported to have the symptoms of LBP and NP which is affecting the normal life and work performance. In 15 cases, the workers taking the advice of health professionals and they are in medications. Due to these symptoms, 8 cases reported that they have taken sick leave. When the 4-month follow-up period is divided into four 1-month sub period, in these period of time the trend of LBP and NP incidence rate is increased from the first sub period. The strength of handgrip, leg, and back are significantly lower for NP and LBP cases than the non-NP and non-LBP cases as shown in Table 4. Table 5 shows the factors that are significantly associated with NP and LBP based on the multivariate analysis. These factors are high stress, $BMI \leq 26$, family members with back pain, poor back-pain preventive behavior, and inappropriate width for the use of workstation. The office workers who has $BMI \leq 26$ will be having higher risk for NP and LBP which is about 3.4 times greater and those having $BMI > 26$ will be less risk having CI 95%. The LBP and NP will be applicable for the worker whose family member are affected with such kind of factors when compared to others whose family members are not affected with those back pains. Compared to no-stress workers, LBP and NP is higher about 4.2 times when they are having high stress. The workers who is having prevention behavior very poor for back pain has high risk of development for NP and LBP about 3.85 time more. Inappropriate workstation for the workers will have high risk of LBP and NP due to the width when compared with appropriate workstation.





RESULT AND DISCUSSION

The use of this prospective grouping with regular follow-up participants with the subjects over the entire period of 4-month proves that this study minimizing the risk of recall biases and becomes a valuable strength in finding the high incidence rate for LBP and NP for the professional office workers. In the present study, the higher incidence rate explained by the difference for the current eligibility criteria. The participants are selected based on the working time which should be minimum of 5 hours per day in office with computer. When compared with the Malaysian study [23], this study gives a better result in determining the risk of NP and LBP and also analyze the cause for these factors which is due to sitting in same position for longer time. For some cases, the participants are taking sick leave which is reported in the study and it occurred due to NP and LBP. Increase in absentees among the office worker can lead to development of LBP and NP for other. This type of mislead can create additional incident of negative impact on management and academic activities. The general nature of the workers in office with the computers involved by sitting in a fixed position for typing documents and in front of screen and performing huge tasks for atleast 4 to 5 hours a day. In our study, the risk of LBP and NP is increased due to sitting for longer hours with a computer. The NP and LBP is provoked by the potential roles such as prolonged sitting and inappropriate workstation design.

This is the clear explanation which is supported for this study for finding the poor preventive behavior and sitting for long time which are significantly correlated with NP and LBP. Furthermore, the risk in development of NP and LBP is more when noticing the BMI is lesser than or equal to 25 for the office workers when compared with those who is having higher BMI which is greater than 25. From the previous study in [24], the BMI >30 will lead to chronic LBP but when it is compared with our study the findings are different as it gives for 25. This is due to the follow-up of our study is about only for 4-month which major office works having less BMI. Moreover, the development of NP and LBP is higher than the effect of BMI due to the physical dimensions of individual office workers in the workstations. This is particularly for those office workers who spent long time with the computers. From this present study, an important factor is found is that the relationship between increased risk and poor back-pain preventive behavior of NP and LBP. Furthermore, poor muscle flexibility or strength is also correlated with the development of LBP and NP. These analysis explains the office workers to be aware of self-preventive behavior and regular exercise to overcome NP and LBP problems. Therefore, process of this ergonomics study is processed for ensuring the routine design of workstations and the physical needs are expected for individual workers. Other aspect such as lighting intensity plays an important role which will lead to eye strain for the prolonged workers for long term and can cause back pain, shoulder, and neck.

CONCLUSION

In this research, high prevalence of NP and LBP complaints are observed among office workers. These complaints are influenced by QWL particularly in shoulders, neck, back pain, leg, and upper back. The incidence rate for NP and LBP is proven to be increasing for 4-month period of follow-up which gives a health related warning and its effects among office workers because of longer vulnerable towards the hazards of office work. However, improving the QWL will leads to reduction in NP and LBP. The indication from the results show that the improvement in QWL can affect the office work hazards such as LBP and NP. In this study, the analysis shows that the various ergonomics factors such as BMI, previous medical complications, family members having problems regarding NP and LBP, stress, chronic disease, age factor, work experience, hours of working, environmental factor, and lighting intensity can increase the incidence rate of LBP and NP. The consideration of these ergonomic factors are the important aspects which helps in reducing the LBP and NP.





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Table 1 Questionnaire for Office Workers

	Section 1	Answers
1.	Willing to participate	Yes/No
2.	Name of the Office Worker	Character
3.	Age	Number
4.	Gender	Male/Female/Transgender
5.	Work Experience	Years





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6.	Marital Status	Single/Married
7.	Total Family Members	Numbers
8.	Height and weight of the worker	Numbers in cm and kg
9.	Present Address of the worker	-
10.	Do you experienced NP and LBP or any one	Yes/No
Section 2		
1.	Current Health Condition	Statement
2.	History of Congenital Disease	Yes/No
3.	History of Trauma Disease	Yes/No
4.	History of Chronic Disease	Yes/No
5.	Body Mass Index (BMI)	Condition
Section 3		
1.	Appearance and Behavior	Statement
2.	Mood of the worker	Statement
3.	Speech of the worker	Polite/Harsh
4.	Thoughts of the worker	Statement
5.	Perception of the worker	Statement
6.	Sensorium and Cognition of worker	Statement
7.	Judgement and Insight	Statement
8.	Past psychiatric and medical history	Statement
9.	Psychological Stress	Yes/No
Section 4		
1.	Daily working hours	Numbers in Hours
2.	Weekly working hours	Numbers in Hours
3.	Sitting duration in seat	Numbers in Hours
4.	Break timing in working hours	Numbers in Minutes/Hours
5.	Preventive behavior for back and neck pain	Yes/No
6.	Suitability of workplace	Yes/No
7.	Regular exercise	Yes/No
8.	Lifting heavy objects	Yes/No
9.	Dimensions of workplace	L*B*H
10.	Handgrip Strength	Numbers
11.	Leg and back strength	Numbers
12.	Muscle flexibility	Numbers
13.	Lighting intensity	Calculated intensity

Table 2 Variables for Ergonomic Factors of Office Workers

S.No.	Variables
1.	Age
2.	Gender
3.	Work Experience
4.	BMI
5.	Weekly Working-Hours
6.	Daily Working-Hours
7.	Marital-Status
8.	QWL
9.	Neck Pain
10.	Low Back Pain





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11.	Trunk
12.	Legs
13.	Upper Arm
14.	Lower Arm
15.	Wrist
16.	Light Intensity
18.	Job Satisfaction
19.	Previous Disease
20.	Psychological Stress

Table 3 Incidence Rate for NP and LBP

Follow-Up Periods	Collected Numbers		Collected Incidence Rate (%)		New Cases reported	
	Cases	Non-Cases	LBP	NP	LBP	NP
1-month	74	118	53.8	52.6	74	73
2-month	112	70	67.5	64.8	38	35
3-month	126	56	72.5	71.6	52	50
4-month	146	46	80.7	79.6	72	71

Table 4 NP and LBP Cases for Baseline Physical Fitness

Variables	LBP and NP		p
	Cases (n=146)	Non-Cases (n=36)	
Leg-Strength (kg)	88.6±3.2	118.0±11.2	0.004
Handgrip-Strength (kg)	31.2±0.9	38.5±2.4	0.003
Back-Strength (kg)	48.6±2.6	68.5±5.8	0.007
Flexibility of Back-Muscle (cm)	5.4±1.3	4.8±1.4	0.341

Table 5 Multivariate Analysis for Potential Risk Factors

Factors	LBP&NP(%)	RR	RR _{AdCI} 95%	p
	Cases			
Gender				
Female	125	1.00	1.00	0.074
Male	57	2.48	2.04 [5.78,0.86]	
Age-Group				
>45	74	1.96	0.99 [4.63, 0.32]	0.992
<45	108	1.00	1.00	
Work-Experience				
>20	68	1.88	1.47 [5.68, 0.42]	0.762
<20	114	1.00	1.00	
BMI				
≤25	146	3.21	3.89 [9.68, 1.42]	0.018
≥25	46	1.00	1.00	
Chronic Disease				
No	96	1.00	1.00	0.167
Yes	86	2.64	2.48 [6.84, 0.86]	
High-Stress				
No	84	1.00	1.00	0.183
Yes	98	3.86	2.84 [9.87, 2.84]	





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Back Pain for Member of Family				
No	76	1.00	1.00	0.098
Yes	106	3.86	2.94 [9.23, 0.96]	
Prevention Behavior of Back Pain				
Good	26	1.00	1.00	0.048
Poor	156	3.97	3.68 [11.26, 1.28]	
Workstation-Width				
Appropriate	78	1.00	1.00	0.026
In-appropriate	104	3.46	5.96 [23.12, 1.68]	
Workstation-Depth				
Appropriate	58	1.00	1.00	0.289
In-appropriate	124	2.45	0.67 [1.97, 0.23]	

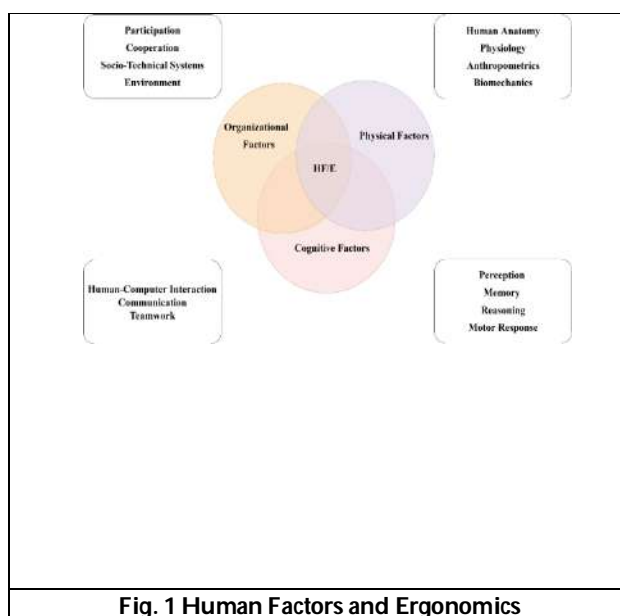


Fig. 1 Human Factors and Ergonomics

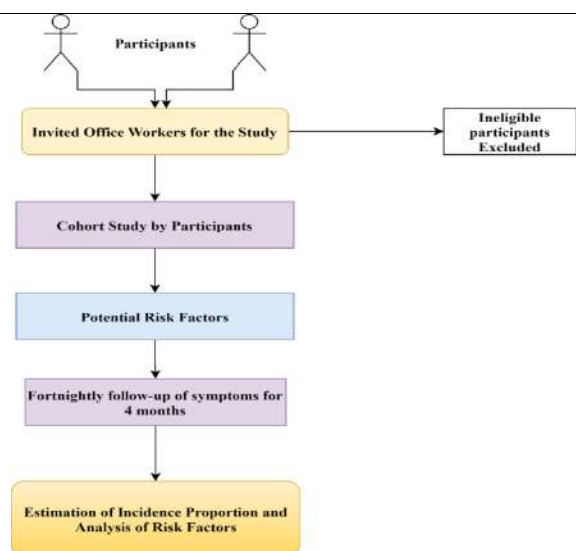


Fig. 2 Process of this Study





An Analysis of Diabetes Awareness among Truck Drivers in Delhi NCR (National Capital Region)

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ABSTRACT

Diabetes is a pressing global health concern, particularly pronounced in India. Among truck drivers, undiagnosed cases and insufficient awareness pose significant risks. The objective is to examine the level of awareness, and adherence to diabetes-related practises among truck drivers, having both diabetic and non-diabetic. A cross-sectional survey was conducted among commercial truck drivers at Transport Nagar in Delhi-NCR, from January 2023 to March 2023. A survey among 108 commercial truck drivers in Delhi-NCR aimed to gauge their awareness and adherence to diabetes-related practices. Findings revealed concerning gaps: while 77.8% had some knowledge of diabetes, only 33.3% understood its organ-specific effects. Alarming, 63.0% had never undergone diabetes testing. These results emphasize the urgent need for targeted interventions to improve awareness and preventive measures among this high-risk group. With diabetes impacting both health and welfare, addressing these gaps is crucial for individual well-being and broader road safety.

Keywords: Awareness, Diabetes, Truck Drivers, Delhi NCR, Road Safety

INTRODUCTION

Diabetes has been a prevalent global public health concern, and India has emerged as the foremost epicentre of diabetes worldwide in recent times. According to the most recent estimate provided by the World Health Organization (WHO), India now exhibits the greatest prevalence of diabetes, with a reported figure exceeding 32



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million people diagnosed with the condition. Based on projections, it is anticipated that this figure will experience a substantial increase to approximately 79.4 million by the year 2030[1]. Truck drivers face an elevated risk of developing diabetes because of their predominantly inactive lifestyle, inadequate dietary choices, and heightened stress levels [2][3]. Commercial truck drivers are at the forefront of the road transportation industry in India, comprising an approximate total of five million individuals [4]. The presence of undetected diabetes and a lack of awareness regarding diabetes among truck drivers pose significant risks to their overall health and well-being [5]. It has been observed that commercial truck drivers are at a heightened risk for cardiovascular risk factors [6]. To effectively manage and mitigate the impact of diabetes, it is crucial to prioritise awareness and acquire comprehensive knowledge on the subject matter [7]. Previous studies have extensively documented the prevalence of diabetes among truck drivers, ranging from 10% to 20% [8] [9]. This study addresses the existing gap in the literature by documenting the levels of awareness, knowledge, and practise of truck drivers, both diabetic and non-diabetic, in relation to diabetes. This will assist policymakers and professionals in programme development to effectively strategize for the future development of diabetes control programmes targeted at this mobile population.

MATERIAL AND METHODS

The present cross-sectional survey was conducted among commercial truck drivers at Transport Nagar in Delhi-NCR, from January 2023 to March 2023. The participants were chosen using a convenient sampling method, resulting in a sample size of 108 commercial truck drivers. The data was collected using a structured questionnaire having both open-ended and closed-ended questions to assess knowledge. The questionnaire underwent a pilot phase involving thirty commercial truck drivers who were not included in the final survey. This pilot phase aimed to test and refine the questionnaire. The questionnaire comprises sections on demographic information, awareness of diabetes-related issues, and healthcare practices related to diabetes. All truck drivers who attended the monthly community health camps organised by the charity hospital in Delhi - NCR, were contacted to participate in the survey. These camps provided drivers with the opportunity to undergo random blood sugar tests using automatic glucometers to assess their diabetes levels. All truck drivers who provided their consent were included in the study. The data was recorded in Microsoft Excel 2017, and subsequent data analysis and interpretation were performed using descriptive statistics, which encompassed measures such as mean and percentage.

FINDINGS AND RESULTS

Referring Table 1, it was found that the average age of the drivers was 33.1 ± 7.7 years. The observed response rate in the study was 93.91%. A significant majority of 102 individuals (94.4%) possessed literacy skills. Among these literate drivers, 26.1% had successfully finished elementary school, 47.7% had attained a high school education, 17.4% had pursued upper secondary education, and a small proportion of 3.5% had achieved a graduation degree. Most of the respondents in the study were married, accounting for 79.1% of the total sample. Additionally, 60.9% of the sample, reported being smokers. Among the smokers, a significant proportion, specifically 77.1%, indicated that they had been smoking for a duration exceeding 6 years. A total of 15 drivers, which represents 13.0% of the sample, reported having a family history of diabetes. Table 2 has shown the details of truck drivers having awareness about diabetes and their source of information. Most truck drivers, namely 73.0% ($n = 84$), demonstrated awareness about fundamental knowledge relevant to diabetes. The average age was 33.7 ± 7.9 years among individuals who possessed knowledge regarding diabetes, whereas it was 30.8 ± 6.4 years among those who were uninformed about the condition. The primary sources of knowledge on diabetes were found to be word of mouth, accounting for 38.0% of respondents, followed by family and friends at 24.0%, and doctors at 29.0%. Out of the truck drivers surveyed, 10.7% exhibited a lack of awareness regarding the typical age of onset for the disease, while 26.2% showed a lack of understanding regarding the diagnostic processes associated with the condition. 33.3% of the total 28 truck drivers demonstrated awareness regarding the specific organs affected by diabetes. However, the remaining respondents either possessed partial knowledge or were completely unaware of the organs impacted by this condition. Table 3 shows Out of the total number of participants, 63.0% of the truck drivers reported that they had never undergone



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diabetes testing. 32.5% of the truck drivers who underwent diabetic testing tested positive for diabetes. These individuals subsequently pursued treatment options encompassing medication, exercise, and dietary modifications. The prevailing viewpoint among a significant proportion of truck drivers is that effective management of diabetes necessitates adherence to a routine medication regimen, regular physical exercise, and dietary modifications.

DISCUSSIONS

The present study explained that most truck drivers fell within the age range of 25 to 50 years. In a study conducted among a significant cohort of truck drivers, it was found that a substantial percentage (77.8%) of participants demonstrated awareness of diabetes. Notably, the primary channel through which this knowledge was acquired was through informal communication, commonly known as word of mouth. A significant proportion of the participants, comprising over 50%, have not undergone diabetes testing. The present study observed a diabetes prevalence rate of 15.5%, which aligns with the findings of Randhawa et al. (2020), who reported a prevalence rate of 16% [9]. Additionally, the National Diabetes and Diabetic Retinopathy Survey 2019 reported that the prevalence of diabetes (defined as blood glucose levels exceeding 200 mg/dl) among truck drivers was 1.3 times higher (16%) compared to the general male population in India (12%). Nevertheless, the frequency of prediabetes across all 15 states was recorded at 10.3% [10]. Misra et al. (2001) observed a higher prevalence of diabetes mellitus at a rate of 11.2%. In the field of international studies, researchers Odeyinka et al. (2017) and Saberi et al. (2011) conducted investigations that revealed a diabetes prevalence rate of around 3% among commercial truck drivers [12] [13] [14]. In a meta-narrative systematic review conducted by Abu Dabrh et al., (2014) an investigation was carried out on the health evaluation of commercial drivers. The study found that the prevalence of diabetes among this population was 33% [15]. The study conducted by Deepa et al. (2005) revealed that a significant proportion of individuals residing in Chennai, around 19.0%, exhibited a lack of awareness regarding the existence of a medical ailment known as diabetes [16]. Truck drivers face an elevated susceptibility to diabetes because of many factors, including a sedentary lifestyle, extended working hours, inconsistent dietary patterns, and restricted availability of nutritious food choices. The limited sample of truck drivers we examined and the inability to offer a definitive diagnosis of diabetes are two limitations of our study. This limited sample size may obstruct the generalizability of the findings to a broader population of truck drivers. Additionally, it is important to acknowledge that the study does not possess the capability to provide a definitive diagnosis of diabetes. One notable strength of the present study lies in the comprehensive nature of the survey, which encompasses not only an examination of knowledge, awareness, and practises pertaining to diabetes but also an evaluation of the health-seeking behaviours exhibited by truck drivers.

CONCLUSION

This study clarified that a significant proportion of truck drivers had knowledge of diabetes and had a broad awareness of the condition. However, a significant proportion of individuals have not undergone testing to determine their diabetes status. It also addresses a gap in the existing scholarly literature by investigating the levels of diabetes awareness, knowledge, and management among truck drivers. Awareness of diabetes and its possible implications is of utmost importance for commercial truck drivers. Unregulated diabetes has the potential to result in significant health concerns, such as ocular impairments, neuropathy, cardiovascular disorders, and an elevated susceptibility to vehicular accidents. The cultivation of awareness among drivers facilitates their comprehension of the significance of effectively managing diabetes, actively seeking medical attention, and embracing health-promoting lifestyle practises.

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Table 1: Demographic Information about Truck Drivers

S.No.	Variables	Distribution of Truck Drivers (N = 108)	
		Frequency	Percentage
1	Age Group		
	21 TO 35	44	38.3
	36 TO 50	40	34.8
	51>	24	20.9
2	Education Level		
	Illiterate	6	5.2
	Primary	30	26.1
	10th	48	41.7
	12th	20	17.4





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	Graduation +	4	3.5
3	Marital Status		
	Married	91	79.1
	Unmarried	16	13.9
	Widower/Separated	1	0.9
4	Smoking Habit		
	Yes	70	60.9
	No	38	33.0
	Occasionally	0	0.0
5	Diabetes in Family		
	Yes	15	13.0
	No	69	60.0

Table 2: Awareness about Diabetes

S. No	Variables	Distribution of Truck Drivers	
		Frequency	Percentage
1	Awareness and Knowledge (N = 108)		
	Yes	84	73.0
	No	24	20.9
2	Resource of information (N = 84)		
	Camp	4	4.0
	Doctor	17	19.0
	Family	13	14.0
	Friend/ Colleague	9	10.0
	Not remember	0	0
	People	35	38.0
	News	6	7.0

Table 3: Diabetes among Truck Drivers

S. No	Variables	Distribution of Truck Drivers	
		Frequency	Percentage
1	Have you ever had a diabetes test before (N = 108)		
	Yes	40	37.0%
	No	68	63.0%
2	Diagnosed with Diabetes (N = 40)		
	Yes	13	32.5%
	No	27	67.5%





RESEARCH ARTICLE

To Check the Awareness and Practice in Pregnant Woman for Infant Oral Health and Self-oral Hygiene

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ABSTRACT

To check the awareness and Practice in Pregnant Woman for Infant Oral Health and Self-oral Hygiene. A self-administered questionnaire was conducted among 120 pregnant women in SGT University, Gurugram. Data were analyzed using SPSS (v. 21), p value <0.05 was considered statistically significant. Most surveyed women were knowledgeable about dental health issues, although a large percentage did not visit dental clinics regularly during pregnancy. The results obtained from the study revealed that the expectant mothers in the higher age groups and with graduate and postgraduate degrees fared better. Overall, the respondents in the present survey displayed average oral health knowledge and positive attitudes to oral health.

Keywords: Oral health, Knowledge, Pregnant women, Practices

INTRODUCTION

To check the awareness and Practice in Pregnant Woman for Infant Oral Health and Self-oral Hygiene

The moment a child is born, the mother is also born. A mother is something absolutely new and so in the child a mother lives on and the family continues to live. "Pregnancy is one of the most important stages in a woman's life. In this stage, a woman feels that she has become responsible not only for her health, but also for the health and well-being of the fetus growing in her. Pregnancy makes a woman more aware of all health issues and how they might relate to or be predisposing factors for her child's future health. Pregnant women thus become more receptive to all



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health information" [1]. Studies have shown that a substantial proportion of pregnant women report that they become acquainted with their oral health problems involving hard and soft tissues during pregnancy. However, most of them discern that such problems are normal to a pregnant woman and blanch away during post-natal periods. With such a notion, most pregnant women abnigate from seeking professional dental consultation and/or are reluctant to undergo certain dental procedures during pregnancy with a trepidation of possible harm to themselves or their babies [2]. There is adequate substantiation that suggests good oral health is advantageous to both the mother and her baby. As an exemplar, maternal periodontal disease has often been associated to preterm birth, low birth weight, and preterm low birth weight. Numerous studies have established that pregnant women have more gingivitis than their non-pregnant peers[3,4] with a prevalence ranging from 30% to 100%.[4,5]The exaggerated inflammatory response of the gums to bacterial plaque known as pregnancy gingivitis has been attributed to the increased secretion of gestational hormones (especially oestrogen and progesterone) during pregnancy [6,7]. Knowledge and attitude of the parents exclusively a mother, forms one of the leading building blocks for establishing optimal oral health among infants. Literature amply documents the fact that good oral health of the mother right from pregnancy could be the key behind it. Hence, appraisal of the knowledge and attitude of expectant mothers using pre-validated questionnaire would help in analyzing and formulating personalized infant oral health promotion programs.

MATERIAL AND METHODS

A supervised, well structured, questionnaire-guided interview in SGT University, Gurugram, Delhi-NCR, was used in the study, allowing closed and open responses. Information on the demographic data, level of education, Oral hygiene knowledge, Infant oral hygiene knowledge, Oral hygiene practice, Pre-natal dental visits of the study subjects was collected. A total of 120 pregnant mothers were recruited with 100% response rate. Questionnaire forms were distributed and collected with the help of a female social worker on the same day from the pregnant mothers while waiting in the antenatal clinic. Descriptive statistics was performed and frequency tables and pie charts were generated. All categorical variables were analysed using SPSS Software. Questionnaires were administered to all consecutive consenting pregnant women who attended the Gynaecology Department of SGT University during the study period. A total of 120 questionnaires were properly completed. The questionnaire comprised of five sections. The first section contained questions on the respondent's Socio Demographic characteristics such as age and educational status. The second section comprised of questions on Oral Hygiene Knowledge. There were fifteen questions in this section evaluating the oral health knowledge of the respondents including understanding and causes of tooth decay and gum disease. The third section comprised of questions on Infant Oral Hygiene Knowledge. This section contained seven questions specially build up to gauge the respected mother's opinion regarding their issue's oral hygiene. The fourth section encompassed questions on Oral Hygiene Knowledge of the mother herself. The fifth section comprised of three questions that helped in assessing the fact that limit the expecting mother's visit to the dentist which mainly included lack of time, insufficient finances and fear.

RESULTS**Demographic Data**

Out of 120 expectant mothers, (n = 83, 69%) were aged between 20-25 years, (n = 27, 22.5%) were aged between 26-30 years, (n = 8, 6.6%) were aged between 31-35 years and (n = 2, 1.6%) were in the age group of 36+ (Table 1) and (Figure 1). Only (n = 2, 1.66%) pregnant females had high school education, (n = 9, 7.5%) had attained post graduate degree whereas majority, (n = 109, 90.83%), had tertiary education (Table 2) and (Figure 2).

Oral Hygiene Knowledge

This section provides a summary of questions which were asked from pregnant women's about oral hygiene knowledge (Table 3). Respondents believed that the following factors prevented tooth decay: cleaning the teeth (n = 99, 82.5%) (Figure 3), eating less amount of sugar (n=105, 87.5%) (Figure 3), whereas (n = 93, 77.5%) regarded



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Pyorrhoea same as Gingivitis (Figure 4). Around (n = 101, 84.16%) (Figure 5) respondents experienced gum problems, (n = 102, 85%) (Figure 6) noticed change in their gums and only, (n = 17, 14.16%) felt cleaning their teeth made them sick (Figure 7). Greater number of the women agreed, (n = 111, 92.5%), that they are cleaning their teeth less often since they became pregnant (Figure 7). Out of 120, only (n= 45, 37.5%) (Figure 8) believed pregnancy itself causes teeth to go bad and only (n = 39, 32.5%) (Figure 9) believed periodontal disease lead to preterm low birth weight deliveries. Out of 120, (n = 66, 55%) (Figure 10) believed dental visits are important during pregnancy. Majority had self-limiting reasons like lack of time (n = 83, 69.16%), deficiency of funds (n = 77, 64.16%), fear of visiting a dentist (n = 29, 24%) (Figure 11) and most of them did not even feel the need of visiting one (n = 77, 66.16%) (Table 6). Only few of them (n = 21, 17.5%), though it is essential to meet a dentist after 6 months (Figure 12).

Infant Oral Hygiene Knowledge (Table 4)

In this section of the questionnaire, the mothers were asked seven questions to judge their awareness regarding infant oral hygiene as depicted in (Figure 13, 14, 15).

Oral hygiene practices (Table 5) (Figure 16)

This section consisted of questions to determine how well the oral hygiene practices are carried out by the patient. Around 35.8% (n = 43) noticed smell from their mouth. Roughly around 7.5 % (n = 9) and 10.8% (n = 13) flossed their teeth and rinsed their mouth with mouth rinse. Not even 5% were aware of the Fluoride and it's benefits.

Pre natal dental visits (Table 6) (Figure 11)

A sizeable portion of the respondents narrowed down their dental visits owing to lack of time (n= 83, 69%). The distress of visiting a dentist (n = 29, 24%) and shortage of finances (n = 77, 64%) were among the other reasons that limited the patient's dental visits.

DISCUSSION

Maintaining good oral hygiene is of utmost importance that one can do for their teeth and gums. Healthy teeth not only enable one to look and feel good, they make it possible to eat and speak properly. A woman's life is affected by pregnancy in many ways, including her oral health. Taking care of oral cavity is important during pregnancy. Being pregnant puts the mother at higher risk for tooth decay, gum disease (also known as "pregnancy gingivitis") and oral growths called "pregnancy tumours" and there is no denying the fact that good oral health during pregnancy is crucial especially in view of the recent studies that poor oral health may result in unfavourable pregnancy outcomes. Daily preventive care which includes proper brushing and flossing, helps stop problems before they even develop and is much less painful, expensive, and worrisome than treating conditions that have been allowed to progress. However such positive behaviour would be influenced by the individual's oral health knowledge and attitudes. While many studies have been conducted on this topic in India in the past. But this study was designed to provide a crystal clear view of the present condition of oral health knowledge, attitude and practices of a sample of pregnant women residing mainly in Haryana. Overall the patients in the present survey showed average oral health knowledge and a very positive attitude to oral health. A good number of pregnant females rightly identified the cause of dental decay but only a small percentage knew the cause of periodontal disease. The results which were obtained from the study showed that the expectant mothers in the higher age groups and with postgraduate and graduate degrees fared better. This response was similar to the finding reported in a survey conducted by Akpabio *et al* [8] in Michigan, USA. Not even 30% (n = 27, 22%) were familiar with the fact that tooth decay can also be caused by bacteria which are transmitted from mother to child by kissing or sharing feeding utensils. Reducing the cariogenic bacteria in pregnant mothers prevents the beginning of colonization of bacteria in their infants. The most probable reasons could be lack of information or proper access to awareness about infant oral health. This finding was in accordance with the report of Kohler *et al* [9]. Hardly 2 % appraised the fact that maternal periodontitis and preterm birth were related. Studies support the fact that blood borne anaerobic bacteria or inflammatory mediators can easily cross placenta. This is in accordance with the reports published by Jeffcoat *et al* [10].





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Notes on Plithogenic Fuzzy M-Subgroup of an M-Group and its Applications

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ABSTRACT

This paper provides some basic frameworks for the study of various algebraic Plithogenic structures. The concept of a Plithogenic Fuzzy M-subgroup has been discussed and introduced here. It has been demonstrated that Plithogenic M-subgroups can also be used to represent subgroups that were previously formed in the classic, fuzzy, intuitionistic fuzzy, and neutrosophic environments. Moreover, several homomorphic properties of the Plithogenic Fuzzy M-subgroup have been explored by introducing function in plithogenic environment.

Keywords: Plithogenic Fuzzy M-subgroup, image and preimage of Homomorphism of Plithogenic Fuzzy M-subgroup.

INTRODUCTION

Crisp Set theory has some disadvantages. When it comes to solving difficulties in real life, it is incredibly inadequate. In handling such cases, L. A. Zadeh's fuzzy set theory (1965) is more dependable. Numerous scholars have applied fuzzy theory to a variety of real-world issues since the theory's inception. However, over time, a number of alternative set theories that is more adept at managing uncertainty than fuzzy sets have evolved. These include the Intuitionistic Fuzzy Set (IFS) (1986, Atanassov. K), Neutrosophic Set (NS) (2005, Florentin Smarandache), Plithogenic





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Set (PS) (2017, Florentin Smarandache), etc. Because of this, most academics favour using set theories to address various real-world issues where uncertainty is significant. In actuality, the Neutrosophic Set is a Fuzzy Set that is further generalised from the Intuitionistic Fuzzy Set. The contributions made by Florentin Smarandache to the advancement of Neutrosophic Set theory are noteworthy. He has, for example, contributed to the development of Neutrosophic measurements and probability (2013, Florentin Smarandache), calculus (2015, Florentin Smarandache & Khalid) etc. Neutrosophic set theory offers a wide range of applications as well. Moreover, Florentin Smarandache (2018) presented the notion of Plithogenic theory, a generalisation of the theories of Classical, Fuzzy, Intuitionistic and Neutrosophic sets. Plithogenic set theory is currently widely used in several practical domains and in a authority of decision making propositions. These notions are crucial for addressing a range of probabilistic issues.

PRELIMINARIES

The basic principles of Fuzzy M-Subgroups (FMSG), Intuitionistic Fuzzy M-Subgroups (IFMSG), and Neutrosophic M-Subgroups of M-group (NMSG) are examined in the following subsection along with some of their most fundamental characteristics.

Definition 2.1.1 (2010, Pandiammal et.al.) Suppose an "M-group" is a mathematical structure $(G, *)$, where G is a set and $*$ is a binary operation defined on a group G . The operation $*$ satisfies the following properties:

1. Closure Property: For every elements u and v in G , then $u * v$ is also in G . i.e. the product of u and v is likewise an element of G .
2. Associative Property: For every elements u, v and w in G , then $(u * v) * w = u * (v * w)$
3. Identity Element: An element e exists in G such that for each element u in G ,

$$e * u = u * e = u.$$
4. m-property: For any element u belongs to G , there exists an element v belongs to G (not necessarily distinct from u) such that $u * v = v * u = e$, where e is the unique element).

Example of an M-group 2.1.1 (2010, Pandiammal et.al.) Consider the set $G = \{0, 1, 2, 3\}$ and define the operation $*$ as addition modulo 4 (denoted by $+$).

The addition table for this set is: Here, the unique element e is 0 since $a + 0 = 0 + a = a$ for all a in G .

Now, the m-property for each element in G :

1. For $a = 0$, $\exists b = 0$ such that $0 + 0 = 0 + 0 = 0$ (using the unique element).
2. For $a = 1$, $\exists b = 3$ such that $1 + 3 = 3 + 1 = 0$ (using the unique element).
3. For $a = 2$, $\exists b = 2$ such that $2 + 2 = 2 + 2 = 0$ (using the unique element).
4. For $a = 3$, $\exists b = 1$ such that $3 + 1 = 1 + 3 = 0$ (using the unique element).

Since each element in G has an element that satisfies the m-property, this set G with the operation $*$ (addition modulo 4) would be an example of an m-group.

Definition 2.1.2: [9] A function $\check{T}: [0,1] \rightarrow [0,1]$ is called a \check{T} -norm if and only if for every a, b, t in $[0,1]$, successive provisions are fulfilled:

- (i) $\check{T}(a, 1) = a$
- (ii) $\check{T}(a, b) = \check{T}(b, a)$
- (iii) $\check{T}(a, b) \leq \check{T}(t, b)$ if $a \leq t$
- (iv) $\check{T}(a, \check{T}(b, t)) = \check{T}(\check{T}(a, b), t)$

Definition 2.1.3: [9] A function $\mathbb{T}: [0,1] \rightarrow [0,1]$ is called a \mathbb{T} -conorm if and only if for every a, b, t in $[0,1]$ successive provisions are fulfilled:

- (i) $\mathbb{T}(a, 0) = a$
- (ii) $\mathbb{T}(a, b) = \mathbb{T}(b, a)$
- (iii) $\mathbb{T}(a, b) \geq \mathbb{T}(t, b)$ if $a \leq t$
- (iv) $\mathbb{T}(a, \mathbb{T}(b, t)) = \mathbb{T}(\mathbb{T}(a, b), t)$





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Definition 2.1.4 (2010, Pandiammal et.al.) If $(G, *)$ is a M-group and a fuzzy subset (FS) A of G is called a **Fuzzy M-subgroup (FMSG)** of an M-group of G the requirements listed below are met:

- (i) $\tilde{U}_A(mab) \geq \tilde{U}_A(a) \wedge \tilde{U}_A(b)$,
- (ii) $\tilde{U}_A(a^{-1}) \geq \tilde{U}_A(a)$, for all a and b in G .

Here $\tilde{U}_A(a^{-1}) = \tilde{U}_A(a)$ and $\tilde{U}_A(a) \leq \tilde{U}_A(e)$, where e is the unique element of G . Also, condition (i) is satisfied by a \tilde{U}_A , then it is said to be a fuzzy M-sub-groupoid of a M-group.

Theorem 2.1.1 (2010, Pandiammal et.al.) If \tilde{U}_A is a Fuzzy M-subgroup of a M-group G iff $\forall a, b \in G, \tilde{U}_A(mab^{-1}) \geq \tilde{U}_A(a) \wedge \tilde{U}_A(b)$

Definition 2.1.5 (2010, Pandiammal et.al.) If \tilde{U}_A is a Fuzzy M-subgroup of a M-group G . Then $\forall a, b \in G$ and $\tilde{U}_A(e) \geq t$ the subgroups \tilde{U}_t are called a level M-subgroups of a M-group \tilde{U}_A .

Definition 2.1.6 (2010, Pandiammal et.al.) If (G, \cdot) is a M-group. An Intuitionistic fuzzy subset A of G is called a **Intuitionistic L-fuzzy M-subgroup (ILFMSG)** of a M-group G if the following essentials are met:

- (i) $\tilde{U}_A(mab) \geq \tilde{U}_A(a) \wedge \tilde{U}_A(b)$, (ii) $\tilde{U}_A(a^{-1}) \geq \tilde{U}_A(a)$,
- (iii) $\tilde{N}_A(mab) \leq \tilde{N}_A(a) \vee \tilde{N}_A(b)$, (iv) $\tilde{N}_A(a^{-1}) \leq \tilde{N}_A(a)$, for all m in M & a and b in G .

Definition 2.1.7 [5] If (G, \cdot) is a group. An Intuitionistic fuzzy subset A of G is said to be a **Neutrosophic Fuzzy M-subgroup (NFSG)** of G , if the requirements listed below are met:

- (i) $\tilde{U}_A(mab) \geq \mu_A(a) \wedge \mu_A(b)$,
- (ii) $\tilde{U}_A(a^{-1}) \geq \mu_A(a)$,
- (iii) $\tilde{I}_A(mab) \leq \nu_A(a) \vee \nu_A(b)$,
- (iv) $\tilde{I}_A(a^{-1}) \leq \nu_A(a)$,
- (v) $\tilde{N}_A(mab) \geq \lambda_A(a) \wedge \lambda_A(b)$,
- (vi) $\tilde{N}_A(a^{-1}) \geq \lambda_A(a)$, for all a & b in G .

Example 2.1.3 [5] If A is a Neutrosophic Set of G and $G = \{1, -1, i, -i\}$ such that,
 $A = \{(1, 0.7, 0.5, 0.4), (-1, 0.7, 0.4, 0.3), (i, 0.8, 0.4, 0.2), (-i, 0.8, 0.4, 0.2)\}$.
 Then A is Neutrosophic M-subgroup of M-group G .

MOTIVATION OF THE WORK

It is evident from the talks above that research on fuzzy subgroups, Intuitionistic fuzzy subgroups, and neutrosophic subgroups has produced a number of productive study areas. Some academics investigated its normal versions, homomorphic properties, and other algebraic structures. Furthermore, other authors investigated the basic properties of these notions and used soft set theory to them. Because of its ability to handle uncertainty, the Plithogenic set theory has attracted a lot of interest lately. Once more, this set theory is more inclusive than the theories of Classical Sets (CS), Fuzzy Sets (FS), Intuitionistic Fuzzy Sets (IFS), and Neutrosophic Sets (NS). Stated differently, the ideas of Plithogenic Fuzzy Subgroup (PFSG), Plithogenic Intuitionistic Fuzzy Subgroup (PIFSG), and Plithogenic Neutrosophic Subgroup (PNSG) will serve as extensions of the Classical Subgroup (CSG), Fuzzy Subgroup (FSG), Intuitionistic Fuzzy Subgroup (IFSG), and Neutrosophic subgroup (NSG) — depending on whether they require further discussion. Once more, it is necessary to study their properties, homomorphic features, and a few more crucial algebraic structures. The following research gaps are discussed in this paper:

However, there is no definition for the term "Plithogenic Fuzzy subgroup."

- ⇒ It is necessary for evaluation whether a Plithogenic fuzzy subgroup can represent a Classical subgroup, Fuzzy subgroup, or Intuitionistic subgroup.
- ⇒ Additionally, nothing is known about the homomorphic properties of the Plithogenic fuzzy M-subgroup.
- ⇒ As a result, we introduced the concept of Plithogenic fuzzy M-subgroups and investigated their algebraic properties.





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CONTRIBUTION OF THE WORK

To investigate some of the homomorphic properties of the Plithogenic Fuzzy M-subgroup of a M-group (PFMSG),

- ⇒ To check whether Plithogenic Fuzzy M-subgroup of a M-group (PFMSG) is a generalization of Classical M-Subgroup, Fuzzy M-Subgroup, Intuitionistic M-Subgroup, and Neutrosophic M-Subgroup of a M-group or not.
- ⇒ To define Plithogenic Fuzzy M-subgroup of a M-group and study its algebraic properties.
- ⇒ In light of the aforementioned gaps, this article aims to fill them by offering some crucial definitions, examples, theories, propositions, etc. in the areas of Plithogenic M-Subgroup and Plithogenic Fuzzy M-Subgroup of a M-group. Additionally, the superiority and efficacy of the Plithogenic M-subgroup over the Classical, Fuzzy, Intuitionistic, and Neutrosophic M-subgroups of a M-group will be discussed. Finally, some significant analysis will be covered, such as the ideas homomorphic and anti-homomorphic properties. Some of the goals that are planned and carried out during this study article are as follows.

DETAILS OF THE WORK

Research Problem

Numerous scholars have examined the basic characteristics and various algebraic structures of the fuzzy subgroups—Neutrosophic, Intuitionistic, and fuzzy—to date. It is known that algebraic structures are preserved by homomorphic functions. Therefore, one must investigate how homomorphism affects those fundamental algebraic characteristics. Homotopy has already been presented and examined by a number of scholars in the contexts of Fuzzy Subgroups, Intuitionistic Fuzzy Subgroups, and Neutrosophic Subgroups. Moreover, several scholars have analyzed the homomorphic properties of the standard forms of the Fuzzy Subgroup (FSG), Intuitionistic Fuzzy Subgroup (IFSG), and Neutrosophic Subgroup (NSG) of a M-group. The term "Plithogenic Fuzzy M-Subgroup" has not yet been defined or investigated. Once more, other Plithogenic subgroups, such as Plithogenic fuzzy subgroup, etc., may be established based on the varying degrees of appurtenance and dissimilarity functions. Moreover, Plithogenic subgroups, including Plithogenic fuzzy subgroups, possess the capacity to evolve into a generalized form of Fuzzy subgroups, Intuitionistic fuzzy subgroups, and Neutrosophic subgroups, as Plithogenic sets represent generalized versions of classical sets, fuzzy sets, Intuitionistic fuzzy sets, and Neutrosophic fuzzy sets. Smarandache has demonstrated that all other set theories may be built using just one set theory, namely the plithogenic theory. Similarly, the ideas of fuzzy subgroup, intuitionistic fuzzy subgroup, and neutrosophic fuzzy subgroup may all be created using simply the Plithogenic subgroup of a group. Another time, in addition to defining these concepts, some fundamental analysis of homomorphic pictures, pre-images, etc., is required. However, one must first comprehend how any mapping behaves in a plithogenic environment before adding homomorphism in a plithogenic subgroup. These fundamental ideas of Plithogenic fuzzy M-subgroups have been presented and examined in this work along with appropriate examples. Earlier, certain key concepts have been presented and are being examined in this introductory part.

Preliminaries

Plithogenic refers to something that is related to creation, evolution, or origin. A Plithogenic set is one that has items with one or more attributes, every one of which is connected to a collection of values. In a Plithogenic set, the degree of appurtenance function, or $d(x, y)$, indicates a connection between an element and the value of any attribute. Additionally, the notation $c(y, y)$, which stands for the degree of dissimilarity or contradiction function, represents the connection between the values of any two qualities. A Plithogenic set is defined formally as follows:

Definition 5.1 (2018, Florentin Smarandache)

If U is a universal set and $A \subseteq U$. A Plithogenic set is called as $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, where $\chi, R_\chi, a_{d_F}, a_{c_F}$ is an attribute or appurtenance, R_χ is the appropriate range of attribute's value, $a_{d_F} : A \times R_\chi \rightarrow [0,1]^s$ is the function of degree of appurtenance (DAF) and $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^t$





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is the degree of contradiction function (DCF) that corresponds to it. In this case, $s, t \in \{1, 2, 3\}$. Notably, the fuzzy degree of contradiction function (FDCF) and fuzzy degree of appurtenance function (FDAF) for $s=1$ and $t=1$ in the definition above will modify. Generally speaking, just take into account FADF and FDCF for simplicity. The following axioms are satisfied in the instance of FDCF: $\forall (u_i, u_j) \in R_\chi \times R_\chi$ $a_{c_F}(u_i, u_j) = 0$ & $a_{c_F}(u_i, u_j) = a_{c_F}(u_j, u_i)$.

At this point, one might want to use $s=2$ or $s=3$ with $t=1$ to improve accuracy. Consequently, we will have,

$a_{d_F} : A \times R_\chi \rightarrow [0,1]^2$ (Intuitionistic fuzzy DAF (IFDAF)) and

$a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^3$ (Neutrosophic DAF (NDAF)) along with a_{c_F} as FDCF).

Furthermore, one can utilize $t=2$ or $t=3$ to extend further and raise the degree of precision and complexity. i.e.

$a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^2$ (Intuitionistic fuzzy DCF (IFDCF)) and

$a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^3$ (Neutrosophic DCF (NDCF)).

Plithogenic sets are a simple way to represent any Classical, Fuzzy, Intuitionistic, or Neutrosophic set. A single attribute with three values for Neutrosophic sets (membership (M), indeterminacy (I), and non membership (NM)), two values for Fuzzy sets (membership (M), and non membership (NM)) and one value for membership (M) in the Crisp set establishes a distinction between intuitionistic fuzzy sets, classical sets, fuzzy sets, and neutrosophic sets. The Plithogenic set is consequently a generalization of these sets. The fuzzy subgroup, the intuitionistic fuzzy subgroup, and the neutrosophic subgroup have the following initial homomorphic properties. Understanding the implications of homomorphism in the Plithogenic fuzzy subgroup, Plithogenic Intuitionistic fuzzy subgroup, and Plithogenic neutrosophic subgroup will be made easier by referring to these essential properties.

Definition 5.2 (1979, Anthony & Sherwood) A fuzzy set x of G is called as supremum, if for any $x' \subseteq x$, $\exists m_0 \in x'$, this means that $x(m_0) = \sup_{m \in x'} x(m)$.

Theorem 5.1 (1979, Anthony & Sherwood)

The image (supremum image) of x is a fuzzy subgroupoid on $I(x)$ with regard to T if x is a fuzzy subgroup of G based on a continuous t -norm \check{T} and I is a homomorphism of G .

Theorem 5.2 (1971, A. Rosenfeld)

Any fuzzy subgroup with supremum property is a homomorphic image of its pre-image.

Theorem 5.3 (2011, Sharma)

Preimage of an Intuitionistic Fuzzy subgroup f of G_2 if f is a homomorphism of a group G_1 into another group G_2 .

Theorem 5.4 (2011, Sharma)

An image of an Intuitionistic Fuzzy subgroup f of G_2 if f is a surjective homomorphism of a group G_1 into another group G_2 .

Theorem 5.5 (2015, Cetkin & Augiin)

Any homomorphic subgroup's pre-image or homomorphic image is a Neutrosophic subgroup. Since Plithogenic subgroup is a generalization of Classical set, fuzzy set, Intuitionistic fuzzy set, and Neutrosophic set, it is assumed that it is superior than Classical subgroup, Fuzzy subgroup, Intuitionistic fuzzy subgroup, and Neutrosophic subgroup. We have proposed many kinds of Plithogenic M-subgroups and examined their homomorphic properties in the next section.



**PLITHOGENIC SUBGROUPS (2019, Florentin Smarandache)****Definition 6.1 (2018, Florentin Smarandache)**

If G is a general set and $A \subseteq G$. A Plithogenic set is represented as $A_s = (A, \chi, R_\chi, \wp_{d_F}, \wp_{c_F})$, where $\chi, R_\chi, \wp_{d_F}, \wp_{c_F}$ is an attribute or appurtenance, R_χ is the corresponding range of attribute's value, $\wp_{d_F} : A \times R_\chi \rightarrow [0,1]^s$ is the degree of appurtenance function (DAF) and $\wp_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^t$ is the corresponding degree of contradiction function (DCF). Here $s, t \in \{1, 2, 3\}$. Also note that for $s=1$ and $t=1$ in the description above, will become a fuzzy DCF (FDCF) and a fuzzy ADF (FADF). Usually, only FADF and FDCF are taken into consideration. The following axioms are met in the case of FDCF:

$$\forall (u_i, u_j) \in R_\chi \times R_\chi \quad \wp_{c_F}(u_i, u_j) = 0 \text{ \& \; } \wp_{c_F}(u_i, u_j) = \wp_{c_F}(u_j, u_i).$$

A further instance of $s=2$ or $s=3$ with $t=1$ may be desired to improve accuracy. In that illustration, we obtain,

$$\wp_{d_F} : A \times R_\chi \rightarrow [0,1]^2 \text{ (Intuitionistic fuzzy DAF (IFDAF)) and}$$

$$\wp_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^3 \text{ (Neutrosophic DAF (NDAF)) along with } \wp_{c_F} \text{ as FDCF.}$$

Again, to generalize further and increase the level of accuracy and complexity one may take $t=2$ or $t=3$ i.e.

$$\wp_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^2 \text{ (Intuitionistic fuzzy DCF (IFDCF)) or}$$

$$\wp_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]^3 \text{ (Neutrosophic DCF (NDCF))}$$

Definition 6.1 Plithogenic Fuzzy Subgroup (2019, Florentin Smarandache)

If $A_s = (A, \chi, R_\chi, \wp_{d_F}, \wp_{c_F})$ is a Plithogenic set of a group G . Where χ is an attribute, R_χ is a range of all attribute's values, $\wp_{d_F} : A \times R_\chi \rightarrow [0,1]$ is the corresponding FADF and $\wp_{c_F} : A_\chi \times A_\chi \rightarrow [0,1]$ is the corresponding FDCF. Then A_s is called a PFSG of G if and only if \wp_{d_F} is a fuzzy subgroup i.e. in other words if and only if $\forall (x_1, y_1), (x_2, y_2) \in A \times R_\chi$. The subsequent conditions are fulfilled:

- I. $\wp_{d_F}((x_1, y_1) \cdot (x_2, y_2)) \geq \min\{\wp_{d_F}(x_1, y_1), \wp_{d_F}(x_2, y_2)\}$ and
- II. $\wp_{d_F}((x_1, y_1)^{-1}) \geq \wp_{d_F}(x_1, y_1)$

A set of all Plithogenic Fuzzy subgroup of a group G is denoted as PFSG (G).

Example 6.1 (2019, Florentin Smarandache)

If $A_s = (A, \chi, R_\chi, \wp_{d_F}, \wp_{c_F})$, is a Plithogenic set of a group G , where $\wp = \{a, b, ab, e\}$ is the Klein's four group, is an attribute, is a group collection of two attribute of two attribute values (here, $c^2 = e'$ and e' is the unit element). Also, $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ and $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ are respectively corresponding FADF and FDCF defined in Table 1 and Table 2. Then, $A_s \in PFSG(G)$. Consider a note while both a_{d_F} and a_{c_F} are Fuzzy sets in the definition above, only on a_{d_F} the conditions for a Fuzzy subgroup has been assigned because a_{c_F} will only become a fuzzy subgroup if $\forall (u_i, u_j) \in V_\psi \quad p_{c_F}(u_i, u_j) = 0$.





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Example 6.2 (2019, Florentin Smarandache)

If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, is a Plithogenic set of a group G , where $\mathcal{O} = \{1, -1, i, -i\}$ is a group, χ is an attribute, $R_\chi = \{a, b, ab, e\}$ is the Klein four-group. Also, $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ and $a_{c_F} : R_\chi \times R_\psi \rightarrow [0,1]$ are subsequently corresponding FDAF and FDCF.

Theorem 6.1 (2019, Florentin Smarandache)

If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F}) \in PFSG(G)$ iff $a_{d_F}((u_1, v_1) \cdot (u_2, v_2)^{-1}) \geq \min\{a_{d_F}(u_1, v_1), a_{d_F}(u_2, v_2)\}$.

Theorem 6.2 (2019, Florentin Smarandache)

Any Classical subgroup is a Plithogenic fuzzy subgroup (Considering that two singleton classical groups are united to form an equivalent attribute value set).

Theorem 6.3 (2019, Florentin Smarandache)

Any Fuzzy subgroup is a plithogenic fuzzy subgroup (Considering that a singleton classical subgroup is the equivalent attribute value set).

HOMOMORPHISM OF PLITHOGENIC SUBGROUP

If χ is an attribute and R_χ is the prescribed range of values for that attribute and $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, is a Plithogenic set of a group G . Also, if f is a function defined on $G \rightarrow R_\chi$. Then the image of A_s is denoted as

$A'_s = (A', \chi, R'_\chi, a'_{d_F}, a'_{c_F})$, where $a'_{d_F} : A' \times R'_\chi \rightarrow [0,1]$ is defined as $a'_{d_F}(u_2, v_2) = \sup_{\substack{u_1 \in f^{-1}(u_2) \\ v_1 \in f^{-1}(v_2)}} a_{d_F}(u_1, v_1)$

and $a'_{c_F} : R'_\chi \times R'_\psi \rightarrow [0,1]$ is defined as $a'_{c_F}(v_3, v_4) = \sup_{\substack{v_1 \in f^{-1}(v_3) \\ v_2 \in f^{-1}(v_4)}} a_{c_F}(v_1, v_2)$. Also if,

$P'_s = (P', \psi, V'_\psi, p'_{d_F}, p'_{c_F})$ is a Plithogenic Set of $f(G)$ then the pre image of A'_s will be denoted as

$A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, where $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ is defined as

$a_{d_F}(u_1, v_1) = a'_{d_F}(f(u_1), f(v_1)), \forall (u_1, v_1) \in A \times R_\chi$, $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ is defined as

$a_{c_F}(v_1, v_2) = a'_{c_F}(f(v_1), f(v_2)), \forall (v_1, v_2) \in R_\chi \times R_\chi$.

Theorem 6.4 (2019, Florentin Smarandache)

A Plithogenic fuzzy subgroup's homomorphic preimage is also a Plithogenic fuzzy subgroup.

PROPOSED NOTIONS OF PLITHOGENIC FUZZY M-SUBGROUP OF A M-GROUP

Definition 7.1 (Plithogenic Fuzzy M-Subgroup of a M-group)

If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, be a Plithogenic set of an M-group G . Where χ is an attribute, R_χ is a range of all attribute's values, $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ is the corresponding FDAF and $a_{c_F} : A_\chi \times A_\chi \rightarrow [0,1]$ is the corresponding FDCF. Then, A_s is a PFMSG of G iff a_{d_F} is a fuzzy M-subgroup i.e. in other words if and only if,

$\forall (a_1, b_1), (a_2, b_2) \in A \times R_\chi$ The subsequent conditions are fulfilled:

I. $a_{d_F}(m(a_1, b_1) \cdot (a_2, b_2)) \geq \min\{a_{d_F}(a_1, b_1), a_{d_F}(a_2, b_2)\}$ and





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$$\text{II. } a_{d_F}(m(a_1, b_1)^{-1}) \geq a_{d_F}(a_1, b_1)$$

A set of all Plithogenic Fuzzy M-subgroup of a M-group G is denoted as PFMSG(G).

Illustration 7.1

If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, is a Plithogenic set of an M-subgroup G, where $\wp = \{p, q, pq, e\}$ is the Klein's group, $R_\chi = \{\hat{a}, e'\}$ is a attribute & a M-group consisting of two attribute of two attribute values (here, $\hat{a}^2 = e'$ and e' is the neutral element). Also, $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ and $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ are respectively corresponding FDAF and FDCF defined in Table 2 and Table 3. Then, $A_s \in \text{PFMSG}(G)$. Consider a note that in the above Definition, both a_{d_F} & a_{c_F} are Fuzzy sets but only on a_{d_F} , the Fuzzy M-subgroup's requirements have been assigned because a_{c_F} will transform a Fuzzy M-subgroup of M-group only in the case that $\forall (a_i, b_j) \in R_\chi, a_{c_F}(a_i, b_j) = 0$.

Illustration 7.2 If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, is a Plithogenic set of a M-subgroup of a M-group G, where $\wp = \{1, -1, i, -i\}$ is a cyclic group, χ be an attribute, $R_\chi = \{p, q, pq, e\}$ is the Klein four-group. Also, let $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ and $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ are FDAF and FDCF correspondingly, as indicated in Table 3 and Table 4.

Illustration 7.3

If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, is a Plithogenic set of a M-group G, where $\wp = \{1, -1, i, -i\}$ is the Klein four-group, χ is an attribute, $R_\chi = \{1, \omega, \omega^2\}$, is the M-group. Also, let $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ and $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ are FDCF and FDAF correspondingly, as indicated in Table 5 and Table 6.

Theorem 7.1

If $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F}) \in \text{PFMSG}(G)$ iff

$$a_{d_F}(m(u_1, v_1).(u_2, v_2)^{-1}) \geq \min\{a_{d_F}(u_1, v_1), a_{d_F}(u_2, v_2)\}$$

Proof: Clearly proved.

One can manage ambiguous, inconsistent, and indeterminate data by using Plithogenic Set. It is now more general than the Neutrosophic Set, the Classical Set, the Fuzzy Set, and the Intuitionistic Fuzzy Set. Therefore, it can be shown that Plithogenic Fuzzy M-subgroup has the potential to be broader than Neutrosophic, Classical, Fuzzy, and Intuitionistic subgroups. The pre-eminence properties of Plithogenic Fuzzy M-subgroups have been described with appropriate reasons in the next section.

PLITHOGENIC FUZZY M-SUBGROUP AS A GENERALIZATION OF OTHER M-SUBGROUP OF AN M-GROUP

Theorem 8.1: Any Classical M-subgroup is a Plithogenic fuzzy M-subgroup of M-group (Given that two singleton classical M-subgroups of an M-group are unions to form the corresponding attribute value set)

Proof: If ζ is a classical M-subgroup of M-group G.





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So, $\zeta \subseteq G$ and hence ζ is a Plithogenic set of a M-group G . Here, one may consider corresponding χ = "appurtenance", $R_\chi = \{A, AB\}$ with cardinality 2,

$$a_{d_F} : \zeta \times R_\chi \rightarrow [0,1]$$

$$a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$$

Here

$$a_{c_F}(A, A) = 0,$$

$$a_{c_F}(AB, AB) = 0$$

and

$$a_{c_F}(A, AB) = 1$$

Also, R_χ can be considered as

$$R_\chi = \{A\} \cup \{AB\},$$

Where $\{A\}$ and $\{AB\}$ are singleton Classical M-subgroup of M-group of G . Also,

$$a_{d_F}(a, A) = 1 \text{ and } a_{d_F}(a, AB) = 0.$$

Now,

$$\forall a_1 a_2 \in \zeta a_1 a_2^{-1} \in \zeta$$

$$a_{d_F}(a_1, A) = 1 \text{ and } a_{d_F}(a_2, A) = 1 \text{ imply that,}$$

$$a_{d_F}(a_1 a_2^{-1}, A) = 1$$

clearly proved that

$$a_{d_F}(a_1, A) \cdot (a_2, A)^{-1} = 1 \geq 1 \wedge 1 = a_{d_F}(a_1, A) \wedge (a_2, A).$$

Similarly, $\forall a_1 a_2 \notin \zeta$ it can be proved that

$$a_{d_F}(a_1, AB) \cdot (a_2, AB)^{-1} = 0 \geq 0 \wedge 0 = a_{d_F}(a_1, AB) \wedge (a_2, AB).$$

Hence, $\zeta \in PFMSG(G)$.

Therefore, any Classical M-subgroup is a Plithogenic fuzzy M-subgroup of M-group.

Theorem 8.2

Any Fuzzy M-subgroup is a plithogenic fuzzy M-subgroup of M-group (considering that the appropriate attribute value set is an M-group's singleton classical M-subgroup).

Proof:

Assume that $\eta \in FMSG(G)$

So, $\eta \in FS(G)$ and therefore $\eta \in PS(G)$.

Here one may consider corresponding χ = "appurtenance", $R_\chi = \{A, AB\}$ with cardinality 1,

$$a_{d_F} : \zeta_\eta \times R_\chi \rightarrow [0,1] (\zeta_\eta = \{m \in U : (m, \alpha(m)) \in \alpha\}) \text{ and}$$

$$a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$$

with $a_{c_F}(A, A) = 0$. Note that here

$$a_{d_F}(a, A) = \alpha(a) \text{ in } [0,1].$$





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Then, $\forall a_1 a_2 \in \mathcal{C}_\eta$,

$$\alpha(ma_1 a_2^{-1}) \geq \min\{\alpha(a_1), \alpha(a_2)\}$$

$$\Rightarrow a_{d_F}(ma_1 a_2^{-1}, A) \geq \min\{a_{d_F}(a_1, A), a_{d_F}(a_2, A)\}$$

$$\Rightarrow a_{d_F}(m(a_1, A).(a_2^{-1}, A)) \geq \min\{a_{d_F}(a_1, A), a_{d_F}(a_2, A)\}$$

$$\Rightarrow a_{d_F}(m(a_1, A).(a_2, A)^{-1}) \geq \min\{a_{d_F}(a_1, A), a_{d_F}(a_2, A)\}$$

Hence, from it can be concluded that, $\eta \in \text{PFMSG}(G)$.

Homomorphism of Plithogenic Fuzzy M-Subgroup of a M-group:

If χ is an attribute and R_χ is the subsequent range of attribute's values and $A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$ is a Plithogenic set of an M-group G . Also, if f is a function defined on $G \cup R_\chi$. Then the image of A_s is denoted as

$$A'_s = (A', \chi, R'_\chi, a'_{d_F}, a'_{c_F}), \text{ where } a'_{d_F} : A' \times R'_\chi \rightarrow [0,1] \text{ is defined as } a'_{d_F}(x_2, y_2) = \sup_{\substack{x_1 \in f^{-1}(x_2) \\ y_1 \in f^{-1}(y_2)}} a_{d_F}(x_1, y_1)$$

and $a'_{c_F} : R'_\chi \times R'_\chi \rightarrow [0,1]$ is defined as $a'_{c_F}(y_3, y_4) = \sup_{\substack{y_1 \in f^{-1}(y_3) \\ y_2 \in f^{-1}(y_4)}} a_{c_F}(y_1, y_2)$. Also if,

$P'_s = (P', \psi, V'_\psi, p'_{d_F}, p'_{c_F})$ is a Plithogenic Set of $f(G)$ then the preimage of A'_s will be indicated as

$A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, where $a_{d_F} : A \times R_\chi \rightarrow [0,1]$ is defined as

$a_{d_F}(x_1, y_1) = a'_{d_F}(f(x_1), f(y_1)), \forall (x_1, y_1) \in A \times R_\chi$, $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ is defined as

$a_{c_F}(y_1, y_2) = a'_{c_F}(f(y_1), f(y_2)), \forall (y_1, y_2) \in R_\chi \times R_\chi$.

Theorem 8.1.1

Homomorphic preimage of a Plithogenic fuzzy M-subgroup of M-group is a Plithogenic fuzzy M-subgroup of M-group

Proof: If χ is an attribute and A'_χ is the range of values for the relevant characteristic and

$A'_s = (A', \chi, R'_\chi, a'_{d_F}, a'_{c_F})$, is a Plithogenic fuzzy M-subgroup of M-group $f(G)$, where f is a homomorphism on $G \cup A_\chi$.

Therefore, $a'_{d_F} : A' \times R'_\chi \rightarrow [0,1]$ is Fuzzy M-subgroup and

$a'_{c_F} : R'_\chi \times R'_\chi \rightarrow [0,1]$ is a Fuzzy set.

Then preimage of P'_s is denoted as

$A_s = (A, \chi, R_\chi, a_{d_F}, a_{c_F})$, where

$a_{d_F} : A \times R_\chi \rightarrow [0,1]$ is defined as

$a_{d_F}(x_1, y_1) = a'_{d_F}(f(x_1), f(y_1)), \forall (x_1, y_1) \in A \times R_\chi$ and $a_{c_F} : R_\chi \times R_\chi \rightarrow [0,1]$ is described as

$a_{c_F}(y_1, y_2) = a'_{c_F}(f(y_1), f(y_2)), \forall (y_1, y_2) \in R_\chi \times R_\chi$.

$p_{c_F} : V_\psi \times V_\psi \rightarrow [0,1]$ is defined as





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Assume that, $(m_1, u_1), (m'_1, u'_1) \in P \times V_\psi$, then

$$\begin{aligned} p_{d_F}(m(m_1, u_1), (m'_1, u'_1)) &= p_{d_F}(m_1 m'_1, u_1 u'_1) \\ &= p_{d_F}(f(m_1 m'_1), f(u_1 u'_1)) \\ &= p'_{d_F}((f(m_1), f(u_1)), (f(m'_1), f(u'_1))) \\ &\geq \min\{p'_{d_F}((f(m_1), f(u_1)), p'_{d_F}(f(m'_1), f(u'_1)))\} \text{ (As } p'_{d_F} \text{ is a FMSG)} \\ &= \min\{p_{d_F}(m_1, u_1), p_{d_F}(m'_1, u'_1)\} \end{aligned}$$

Also,

$$\begin{aligned} p_{d_F}(m_1, u_1)^{-1} &= p_{d_F}(m_1^{-1}, u_1^{-1}) \\ &= p'_{d_F}(f(m_1^{-1}), f(u_1^{-1})) \\ &= p'_{d_F}(f(m_1)^{-1}, f(u_1)^{-1}) \\ &= p'_{d_F}(f(m_1), f(u_1))^{-1} \\ &\geq p'_{d_F}((f(m_1), f(u_1))) \\ &= p_{d_F}(m_1, u_1) \end{aligned}$$

So, by p_{c_F} and p_{d_F} is a Fuzzy M-subgroup. Similarly, as p'_{c_F} is a Fuzzy set, its preimage under f that is, p_{c_F} is a Fuzzy set and hence, $P_s = (P, \psi, V_\psi, p_{d_F}, p_{c_F})$ is a Plithogenic Fuzz M-subgroup of M-group G .

Theorem 8.1.2

The homomorphic image of a plithogenic fuzzy M-subgroup of an M-group is a plithogenic fuzzy M-subgroup of itself (given for the supremum property holdings of the FDCF and FDDF).

Proof

If ψ is an attribute and V_ψ is the relevant range of attribute's values and $P_s = (P, \psi, V_\psi, p_{d_F}, p_{c_F})$ is a Plithogenic set of an M-group G .

Also, if f is a homomorphism defined on $G \cup V_\psi$.

Then the image of P_s is denoted as

$$P'_s = (P', \psi, V'_\psi, p'_{d_F}, p'_{c_F})$$

where $p'_{d_F} : P' \times V'_\psi \rightarrow [0,1]$ is denoted as

$$p'_{d_F}(m_2, u_2) = \sup_{\substack{m_1 \in f^{-1}(m_2) \\ u_1 \in f^{-1}(u_2)}} p_{d_F}(m_1, u_1)$$

and $p'_{c_F} : V'_\psi \times V'_\psi \rightarrow [0,1]$ is denoted as $p'_{c_F}(u_3, u_4) = \sup_{\substack{u_1 \in f^{-1}(u_3) \\ u_2 \in f^{-1}(u_4)}} p_{c_F}(u_1, u_2)$. Then





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$$\forall (f(m_1), f(u_1)), (f(m'_1), f(u'_1)) \in P' \times V_\psi,$$

$\exists m_0 \in f^{-1}(f(m_1))$ and $\exists u_0 \in f^{-1}(f(u_1))$ such that

$$p'_{d_F}(m_0, u_0) = \sup_{\substack{m_t \in f^{-1}(m_1) \\ u_t \in f^{-1}(u_1)}} p_{d_F}(m_t, u_t).$$

Also $\exists m'_0 \in f^{-1}(f(m'_1))$ such that

$$p_{d_F}(m'_0, u'_0) = \sup_{\substack{m_t \in f^{-1}(m_1) \\ u_t \in f^{-1}(u_1)}} p_{d_F}(m_t, u_t).$$

Hence,

$$p'_{d_F}(m(f(m_1), f(u_1)), (f(m'_1), f(u'_1))) = p'_{d_F}((f(m_1), f(m'_1)), (f(u_1), f(u'_1)))$$

$$= \sup_{\substack{m_z \in f^{-1}(f(m_1), f(m'_1)) \\ u_z \in f^{-1}(f(u_1), f(u'_1))}} p_{d_F}(m_z, u_z)$$

$$\geq \min\{p_{d_F}(m_0, u_0), p_{d_F}(m'_0, u'_0)\}$$

$$= \min\{p'_{d_F}(f(m_1), f(u_1)), p'_{d_F}(f(m'_1), f(u'_1))\}$$

$$p'_{d_F}(f(m_1), f(u_1))^{-1} = p'_{d_F}(f(m_1)^{-1}, f(u_1)^{-1})$$

$$= \sup_{\substack{m_z \in f^{-1}((f(m_1))^{-1}) \\ u_z \in f^{-1}((f(u_1))^{-1})}} p_{d_F}(m_z, u_z)$$

$$\text{Again } = p_{d_F}(m_0^{-1}, u_0^{-1})$$

$$= p_{d_F}(m_0, u_0)^{-1}$$

$$\geq p_{d_F}(m_0, u_0)$$

$$= p'_{d_F}((f(m_1), f(u_1)))$$

Therefore, by and $P'_s = (P', \psi, V'_\psi, p'_{d_F}, p'_{c_F})$

So, by and p_{d_F} is a Fuzzy M-subgroup of M-group. Again, as p_{c_F} is the image that a Fuzzy set under f , that is, p'_{c_F} is a Fuzzy set and thus, P'_s is a Plithogenic Fuzzy M-subgroup of M-group $f(G)$.

APPLICATIONS OF PLITHOGENIC FUZZY M-SUBGROUP OF AN M-GROUP

Illustration 9.1: Plithogenic Fuzzy M-Subgroup of a Mobile Network

Consider a mobile network with a set of mobile devices. We can define a Plithogenic Fuzzy Subgroup to represent the uncertainty and imprecision in the membership of devices to the network.

Let $G = \{g1, g2, g3, g4\}$ be the set of mobile devices, and μ be a Plithogenic Fuzzy Subgroup of G defined as:

$$\mu(g1) = (0.8, 0.1, 0.1)$$

$$\mu(g2) = (0.5, 0.3, 0.2)$$

$$\mu(g3) = (0.9, 0.05, 0.05)$$

$$\mu(g4) = (0.4, 0.4, 0.2)$$

This Plithogenic Fuzzy M-Subgroup represents the uncertainty and imprecision in the membership of devices to the network.





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Illustration 9.2: Plithogenic Fuzzy M-Subgroup of a Social Network

Consider a social network with a set of users. We can define a Plithogenic Fuzzy M-Subgroup to represent the uncertainty and imprecision in the membership of users to a particular group.

Let $G = \{g_1, g_2, g_3, g_4\}$ be the set of users, and μ be a Plithogenic Fuzzy M-Subgroup of an M-group G defined as:

$$\mu(g_1) = (0.7, 0.2, 0.1)$$

$$\mu(g_2) = (0.4, 0.5, 0.1)$$

$$\mu(g_3) = (0.9, 0.05, 0.05)$$

$$\mu(g_4) = (0.3, 0.6, 0.1)$$

This Plithogenic Fuzzy M-Subgroup represents the uncertainty and imprecision in the membership of users to the group.

CONCLUSION

An essential component of abstract algebra is group theory. Understanding the functions that uphold an object's algebraic qualities is essential for analyzing those properties; in other words, studying homomorphism. Plithogenic fuzzy subgroups, Neutrosophic subgroups, Intuitionistic fuzzy subgroups, and classical subgroups are all generalized into the idea of an M-subgroup. Thus, plithogenic M-subgroups of M-group have been presented and their homomorphism-related consequences have been examined. By employing universal \check{T} -norm and \check{T} -conorm, Plithogenic intuitionistic fuzzy M-subgroup of M-group, Plithogenic Neutrosophic M-subgroup of M-group, and its applications, the majority of the concepts discussed in this study may be further generalized. In this paper, we have explored the applications of Plithogenic Fuzzy M-groups in social networks and mobile networks. We have demonstrated the effectiveness of Plithogenic Fuzzy M-groups in modeling and analyzing complex relationships in social networks and mobile networks.

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Table:1 The addition table for this set

*	0	1	2	3
0	0	1	2	3
1	1	2	3	0
2	2	3	0	1
3	3	1	0	2

Table 2.FDAF

a_{d_F}	a	b	ab	e
A	0.2	0.5	0.3	0.2
e'	0.3	0.2	0.2	0.2

Table 3.FDAF

a_{d_F}	p	q	pq	e
\dot{a}	0.5	0.2	0.3	0.2
e'	0.2	0.3	0.2	0.2





Table 4.FDCF

a_{c_F}	p	e'
a	0	1/2
e'	1/2	0

Table 5. FDAF

$\alpha(a)_{d_{IF}}$	p	q	pq	e
1	0.4	0.4	0.6	0.2
-1	0.4	0.4	0.7	0.2
i	0.4	0.4	0.8	0.2
-i	0.4	0.4	0.8	0.2

Table 6.FDCF

a_{c_F}	ω	e'
1	0	0.5
e'	0.5	0

Table 7. FDAF

$\alpha(a)_{d_{IF}}$	1	ω	ω^2
1	0.2	0.9	0.7
-1	0.2	0.2	0.2
i	0.2	0.4	0.7
-i	0.2	0.2	0.2

Table : 8 Fuzzy DCF

a_{d_F}	a	b	ab	e
A	0	0.4	0.6	0.2





B	0.2	0.4	0.7	0.2
AB	0.4	0.4	0.8	0.2
e^*	0.4	0.4	0.8	0.2

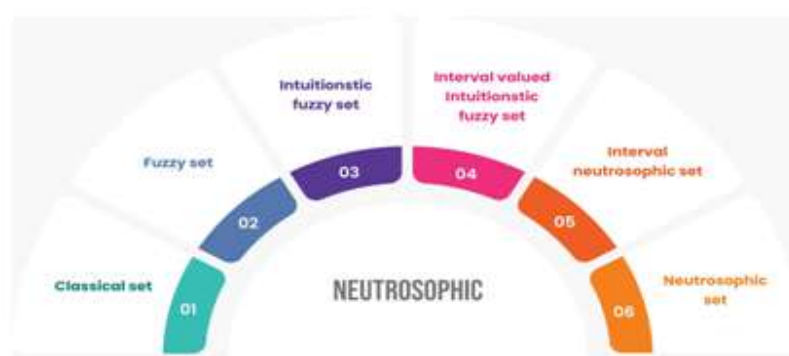


Fig:1





Functional Recovery in Adolescent Transverse Myelitis through Combined Functional Electrical Stimulation (FES) and Exercise Therapy: A Case Report

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ABSTRACT

Transverse Myelitis (TM) is a rare, rapidly progressing autoimmune disorder causing inflammation and demyelination of the spinal cord. Symptoms include motor, sensory, and autonomic dysfunction, with onset in hours and worsening over weeks. Causes range from idiopathic to infections and systemic diseases and recovery varies. One-third fully recover, another third have mild deficits, and the rest face severe disability. The aim of this case study is to assess the physiotherapy interventions in improving balance, gait and functional independence in an adolescent diagnosed with Transverse Myelitis. A 14-year-old female adolescent who developed sudden lower limb weakness, difficulty standing with no bladder control was diagnosed as transverse myelitis and was intervened with intensive evidence-based physiotherapy (PT). A comprehensive assessment included motor, balance, gait, functional independence and balance confidence levels. Based on ICF and outcomes assessed a customized PT protocol including Functional Electrical Stimulation with exercise therapy was given for 7 weeks. This case study showed that tailored evidence-based physiotherapy protocol was effective in improving the targeted functional outcomes and clinically meaningful difference was observed.

Keywords: Functional Electrical Stimulation, rehabilitation, spinal cord disorder, Transverse myelitis.





INTRODUCTION

Transverse myelitis is a rare neurological condition affecting the spinal cord (1). The term “Myelitis” simply refers to the inflammation of the spinal cord and the term “Transverse” describes the position of the inflammation, that is, across the width of the spinal cord (2). It is a rapidly progressive autoimmune disease that results in demyelination of the spinal cord, with symptoms that develop within hours to days and progressively worsen over a period that can last up to several weeks (3,4). In most instance, the exact trigger for the inflammation remains unknown (5). But there are several potential causes for transverse myelitis and the causes can be broadly divided into idiopathic which is the most common cause, post infectious like West Nile virus, herpes viruses and HIV, systemic inflammation that have an association with lupus erythematosus and rheumatoid arthritis, or multifocal central nervous system diseases that includes multiple sclerosis and neuromyelitis optica spectrum disorders (6,7). Neurological symptoms are prominent and include motor, sensory and autonomic dysfunction. Depending on the level of the spinal cord involved, motor symptoms such as paraparesis, which mostly affect the lower limb, can also affect the upper limb (8). Sensory symptoms include pain, dysesthesia and paresthesia. Autonomic features include bladder and bowel incontinence and sexual dysfunction (6,9). The incidence of Transverse Myelitis is 1-8 per million people with peak rates from 10-19 years and 30-39 years without specific etiology (6,10). The incidence of Acute Transverse Myelitis has been estimated to be between 1.7 and 2 per million children per year. Within the pediatric population, idiopathic myelitis has been more frequently reported in children under 5 years and over 10 years of age (7,11). The recommended investigations for transverse myelitis include a MRI of the spine and brain, both with and without gadolinium contrast, to help distinguish between compressive and non-compressive lesions and evaluate for brain lesions. Lumbar puncture for CSF analysis (cell count, protein, glucose, VDRL, oligoclonal bands, IgG index, cytology). Blood tests: anti-AQP4-IgG, anti-MOG, B12, methylmalonic acid, ANA, Ro/SSA, La/SSB, syphilis serologies, HIV antibodies, TSH, and viral tests as needed (6,12). However, the recovery ranges from patient to patient, with approximately one third experience complete recovery, another one third have mild residual deficits and the remaining third remain severely disabled. Consequently, rehabilitation plays a crucial role in the management of transverse myelitis, particularly in severe cases requiring a multidisciplinary approach headed by physiatrists, physical therapists, and occupational therapists. Enhancing endurance, balance, coordination, joint range of motion, reconditioning, mobility, and independence in everyday activities are the main goals of physical therapy rehabilitation. The ultimate goal is to achieve the highest level of independence (12,13).

CASE PRESENTATION

This case study focused on a 14-year-old female adolescent, who was admitted to R.L. Jalappaon 14March,2024 and presented with notable weakness of bilateral lower limbs for a day. After waking up she noticed weakness in the feet and ankles, which was sudden in onset, initially and progressed to knees. She also had difficulty of gripping chappals. However, she was able to appreciate the sensation of chappals; the patient developed buckling of knees on standing and had to support the bed and furniture to balance posture, an hour following that she noticed that she was unable to get up from sitting position, unable to lift lower legs below knee joints. 10 hours after admission, the adolescent had truncal weakness and was catheterized as she lost bladder control. Based on the findings of MRI and Lumbar puncture the diagnosis of Transverse myelitis was made. After the vitals were stabilized, the adolescent was referred to the physiotherapy department at R.L.Jalappa Hospital for rehabilitation to address her lower limb weakness and improve overall functional recovery. She was accompanied by her mother for the treatment. Written informed consent was taken from patient's mother and information sheet were also given and a comprehensive assessment was taken and appropriate treatment protocol was derived, also the procedure was clearly explained to the patient before starting the treatment protocol. The goal of the physiotherapy interventions was to improve strength, balance, gait and make her functional independent.

Physiotherapy intervention

The treatment regimen for this patient, was meticulously crafted to enhance muscle strength and promote greater functional independence. This comprehensive therapeutic protocol not only focused on the strengthening but also



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encompassed various elements essential for balance, gait training, trunk control. The goal was to ensure the adolescent could perform daily activities more effectively and with increased self-sufficiency, improving overall recovery and quality of life. The therapy sessions were conducted at the physiotherapy outpatient department of R.L. Jalappa Hospital, Kolar. Before the commencement of physiotherapy a detailed evaluation was done which comprised of muscle strength, dynamic balance, activity balance confidence and functional independence. The duration of the physiotherapy plan protocol involved 35 sessions and extended over a 7-week period, with five to six sessions each week. Each session lasted between 90 and 150 minutes and with rest between the exercises. Regular counseling was added to the therapy sessions to reduce the risk of depression. This provided emotional support and helped the patient learn coping strategies. The goal was to boost her confidence and mental well-being. Integrating counseling aimed to enhance both her physical and mental health. This approach ensured her active participation in therapy.

HOME EXERCISE

Additionally, the therapy focus was to incorporate home-based exercises and the protocol for the same is given in table-1. The patient was advised to perform exercises at home similar to those done during therapy sessions under the supervision of the caretaker.

STRENGTH TRAINING

As strength training being the ultimate goal of the program, the exercises were planned according to the F.I.T.T principle. Understanding the F.I.T.T principle helps design a therapy plan that will be more effective in reaching the desired goals (16)

Frequency: 4 to 5 days a week

Intensity: included the amount of weight lifted and number of reps and sets. The program initiated with two sets with 10 to 20 reps and increased to four sets of 10 reps with 1kg weight. Progressed to 2kg weight with two sets and 10 to 20 reps.

Time: 60 minutes

Type: The type of resistance used in these exercises includes body weight, weight cuff, and machines.

BALANCE TRAINING

Balance and gait training was performed for 60 mins. Sit to stand was practiced and addressed from the start of the therapy with utmost support. Together with sit to stand various balance exercises were integrated to keep the challenges engaging (table-3&4). It was advanced from requiring minimum support for sit to stand and to being able to do without support. Incorporation of tandem standing, eye closing, standing with feet together were also practiced.

FUNCTIONAL ELECTRICAL STIMULATION

After two weeks, the patient received Functional electrical stimulation (FES) for right side common peroneal nerve to address foot drop. The Functional electrical stimulation (FES) facilitated the dorsiflexion muscle contraction lasted up to 30 contractions with galvanic current. Over three week of period the patient underwent 15 sessions of electrical stimulation. Initially, mild contractions were observed as an extension of big toe with galvanic current stimulation. However, these contractions lasted for only 5-6 repetitions and due to fatigue, there was no further observable contraction. But as the sessions progressed, there was significant changes like: extension of all the toes, and mild dorsiflexion response, which was evident at the end of two weeks of session. Further, significant dorsiflexion contraction was observed for up to 30 repetitions at the end of third week. The patient was advised to use ankle foot orthosis and training was provided with ankle foot orthosis.





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RESULT

The therapeutic intervention, comprising strength training, balance and gait training tailored for the adolescence's rehabilitation, yielded significant improvement across all measured outcomes. The outcome measures of muscle strength, dynamic balance, balance confidence and functional independence are tabulated in table 6, table 7, table 8 & table 9. Also, the outcomes highlight the effectiveness of strength training, balance and gait training in rehabilitating the transverse myelitis patients. This case demonstrates remarkable progress in muscle strength, balance, functional independence.

DISCUSSIONS

Transverse myelitis is a neurological condition that can result in significant impairments in strength, balance and gait. Emerging research suggests that targeted rehabilitation interventions may be effective in alleviating these challenges and enhancing functional outcomes for individuals with transverse myelitis. This case study focused on the acute transverse myelitis case in a young adolescent female who developed severe motor weakness and incontinence. Based on the comprehensive assessment and using ICF, evidence based structured protocol was framed. The intensive therapy included exercises progressively challenging the motor abilities of the patient. The structured protocol included progressive strengthening, balance exercises and gait training with body weight and external resistances. The intensive therapy which was given for 5 to 6 days a week for about 7 weeks and exercise adherence helped to improved significant functional outcome. However, during this intervention the patient was found on & off depressed and it was addressed through counselling. Significant changes in the strength of proximal muscles from 3/5 to 5/5 which aided in the improvement of balance. Similarly, the timed up and go test dynamic balance improved significantly which was observed by the reduction in the time to complete the test also with use of greater assistive to lesser assistive device. The functional independence which was measured using functional independence measure(FIM) scale improved from moderate dependency to mild dependency and also the balance confidence which was markedly low initially, improved remarkably to the greater level confidence from 30% to 60%. Similar studies showed significant improvement in balance, strength and functional independence with strengthening, balance, gait training. (1,15). The selection and integration of various physiotherapy techniques should be tailored to the individual's specific needs and goals. While the existing literature on the rehabilitation of transverse myelitis is very limited, this study adds supportive evidence and suggesting a comprehensive and personalized approach to optimize the functional outcomes in individuals with transverse myelitis.

CONCLUSION

In conclusion, this study demonstrates that the implemented intervention significantly improved strength, balance and functional independence in the patient with Transverse Myelitis. These outcomes highlight the effectiveness of the physiotherapy program in enhancing physical and functional performance and overall improvement of quality of life. Future research should explore long term effect and optimize the protocols in large sample size to further validate and expand upon these results.

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Table 1: Home Based Exercise

	Home Based Exercise	Duration
1	ROM exercises of hip and ankle in both passive and active assisted	All exercises to tolerance
2	Isometric exercise for gluteus, hamstring and abductors, adductors, dorsiflexors and plantar flexors.	10 reps x 2 set
3	Kegels exercise in lying and sitting	3 times a day with 20 reps with 3 sec holds
4	Bridging Abdominal curls	10 reps x 2 sets

Table 2: Phase 1 (Week 1&2) - Exercise Protocol to Facilitate Mobility and Strength

Sl.No	Objectives	Muscle Power	Intervention	Repetition/ Duration
1	To improve ROM and maintain muscle	1/5	Passive range ROM of hip, knee and ankle.	20 reps on both right and left lower limb





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	tone			
		2/5	Progressed to active assisted ROM of hip, knee and ankle	20 reps on both right and left side
2	To strengthen the muscles	3/5	Straight leg raise in flexion and hip abduction and hip extension in right lower limb was done with active assisted	10 reps x 2 sets on both left and right lower limb

Table 3: Phase 2(Week 3-5)- Exercise Protocol to Improve Strength and Balance

Sl.No	Objectives	Muscle Power	Inter Vention	Repetition/ Duration
1	To strengthen the lower limb muscle	3/5	Hamstring curls; Progressed with 1kg weight	10 reps x 2 sets; progressed to 10 reps into 4 reps
			a) Lunges with support b) Bridging exercise with isometric hold. c) Abdominal curls.	Each exercise 10 reps x 4 sets
			Sit to stand initially performed with support	For at least 20 to 30 mins
2	To improve balance	..	Reaching activities in Swiss ball and other head throwing activities	At least for 5 to 10 mins

Table 4: Gait Training

Sl.No	Objectives	Intervention	Duration
1	To create stability to hip flexors and core muscles	a) spot marching b) step up and down	Initiated with 20 reps gradually increased to 30 repetitions
2	Gait training	Parallel bar walking progressed with obstacles	5 rounds over a distance of 4 meters
		Stairs climbing	5 rounds ascending and 5 rounds descending

Table 5: Pre and Post Test of Muscle Strength

MMT	PRE-TEST GRADES		POST-TEST GRADES	
MUSCLES	RIGHT	LEFT	RIGHT	LEFT
Hip flexors	3	3	5	5
Hip extensors	1	1	2	4
Hip abductors	2	2	4	4
Hip adductors	2	2	4	4
Knee flexors	2	3	5	5
Knee extensors	3	3	5	5
Ankle Dorsiflexors	0	3	1	5
Ankle Plantar flexors	0	2	0	4

Table 6: Pre and Post Test of Dynamic Balance

Outcome	Pre-Test	Post-Test
TIMED UP AND GO (TUG)	1 MIN 29 SECS	45 SECS





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Table 7: Pre and Post Test of Balance Confidence

Outcome	Pre-Test	Post-Test
ACTIVITY BALANCE CONFIDENCE(ABC) SCALE	30%	60%

Table 8: Pre and Post Test of Functional Independence

Outcome	Pre	Post
FUNCTIONAL INDEPENDENCE MEASURE (FIM)	89/126	109/126



Figure 1: Bridging exercise with isometric hold



Figure 2: Abdominal curls



Figure 3: Squatting with wall support



Figure 4: Knee extension with external resistance





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Figure 5: Sit to stand exercise



Figure 6: Sit to stand exercise



Figure 7: Staircase training



Figure 8: Parallel bar walking

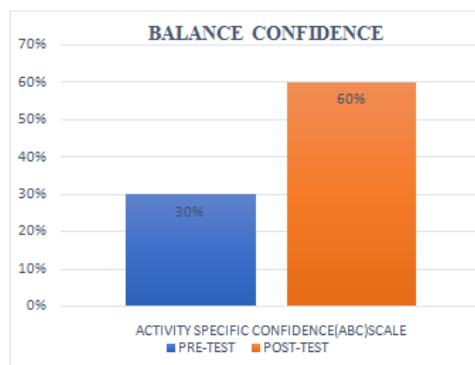


Figure 9: Pre and post-test of balance confidence

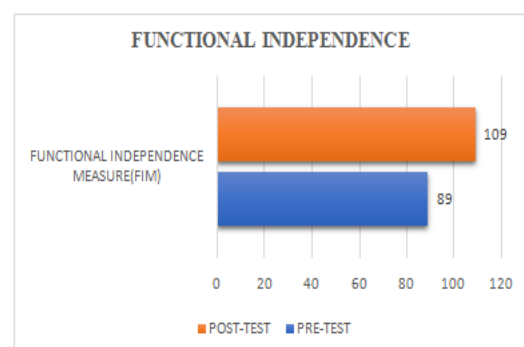


Figure 10: Pre and Post-test of Functional independence





BMJ

ಒಪ್ಪಿಗೆ ಪತ್ರ

BMJ ಪ್ರಕಟಣೆಗಳಲ್ಲಿ ಚಿತ್ರಗಳು ಮತ್ತು/ಅಥವಾ ಅವುಗಳ ಬಗ್ಗೆ ಮಾಹಿತಿಯನ್ನು ಪ್ರಕಟಿಸಲು ರೋಗಿಯ ಒಪ್ಪಿಗೆಗಾಗಿ.

ರೋಗಿಯ ಹೆಸರು:

MEENA

ರೋಗಿಗೆ ಸಂಬಂಧ (ರೋಗಿ ಇಲ್ಲದಿದ್ದರೆ ಈ ನಮೂನೆಗೆ ಸಹಿ ಮಾಡುವುದು):

MOTHER

ರೋಗಿಯ ಫೋಟೋ, ಚಿತ್ರ, ಪಠ್ಯದ ಅಥವಾ ಇತರ ವಸ್ತು (ಮೆಟೀರಿಯಲ್) ಬಗ್ಗೆ ವಿವರಣೆ ವಸ್ತುವಿನ ನಕಲು ಈ ಫಾರ್ಮ್ ಗೆ ಲಗತ್ತಿಸಬೇಕು:

INTENSIVE STRENGTH TRAINING

ತಾತ್ಕಾಲಿಕ ತೀರ್ಮಾನ ಈ ವಸ್ತುವಿನ ಲೇಖನದಲ್ಲಿ ಒಳಗೊಂಡಿರುತ್ತದೆ:

ON PATIENT WITH TRANSVERSE MYELITIS

ಒಪ್ಪಿಗೆ

ನಾನು ಮುನಿರತ್ನಮ್ಮ

[ಸಂಪೂರ್ಣ ಹೆಸರನ್ನು ಮುದ್ರಿಸಿ]

ನನ್ನ/ರೋಗಿಯ ವಿಷಯ BMJ ಪ್ರಕಟಣೆಯಲ್ಲಿ ಕಾಣಿಸಿಕೊಳ್ಳಲು ಒಪ್ಪಿಗೆಯನ್ನು ನೀಡುತ್ತೇನೆ.

ನಾನು ಇದನ್ನು ದೃಢೀಕರಿಸುತ್ತೇನೆ: (ದಯವಿಟ್ಟು ದೃಢೀಕರಿಸಲು ಪಟ್ಟಿಗಳನ್ನು ಟಿಕ್ ಮಾಡಿ)

□ ನನ್ನ/ರೋಗಿಯ ಕುರಿತು ಫೋಟೋ, ಚಿತ್ರ, ಪಠ್ಯ ಅಥವಾ ಇತರ ವಸ್ತುಗಳನ್ನು ನೋಡಿದ್ದೇನೆ

□ BMJ ಗೆ ಸಲ್ಲಿಸಬೇಕಾದ ಲೇಖನವನ್ನು ಓದಿದ್ದೇನೆ

□ ನಾನು ಕಾನೂನುಬದ್ಧವಾಗಿ ಈ ಸಮ್ಮತಿಯನ್ನು ನೀಡಲು ಅರ್ಹನಾಗಿದ್ದೇನೆ.

ನಾನು ಈ ಕೆಳಗಿನವುಗಳನ್ನು ಅರ್ಥ ಮಾಡಿಕೊಂಡಿದ್ದೇನೆ:

(1) ನನ್ನ/ರೋಗಿಯ ಹೆಸರನ್ನು ಲಗತ್ತಿಸದೆಯೇ ವಿಷಯವನ್ನು ಪ್ರಕಟಿಸಲಾಗುವುದು ನಾನು ಅದನ್ನು ಅರ್ಥ ಮಾಡಿಕೊಂಡಿದ್ದೇನೆ, ಅದರೂ ಸಂಪೂರ್ಣ ಅನಾಮಧೇಯತೆಯನ್ನು ಖಾತರಿಪಡಿಸಲಾಗುವುದಿಲ್ಲ. ಉದಾಹರಣೆಗೆ ಯಾರಾದರೂ ಎಲ್ಲಾದರೂ ಆಗಿರಬಹುದು, ನನ್ನನ್ನು/ರೋಗಿಯನ್ನು ಅಥವಾ ಸಂಬಂಧಿಕರನ್ನು ನೋಡಿಕೊಳ್ಳುವವರು - ನನ್ನನ್ನು/ರೋಗಿಯನ್ನು ಗುರುತಿಸಬಹುದು.

(2) ಮೆಟೀರಿಯಲ್ ನನ್ನ/ರೋಗಿಯ ವೈದ್ಯಕೀಯ ಸ್ಥಿತಿ ಅಥವಾ ಗಾಯ ಮತ್ತು ಯಾವುದಾದರೂ ವಿವರಗಳನ್ನು ತೋರಿಸಬಹುದು ಅಥವಾ ಒಳಗೊಂಡಿರಬಹುದು. ನನ್ನ/ರೋಗಿಯ ಮುನ್ನರಿವು, ಚಿಕಿತ್ಸೆ, ಅಥವಾ ಶಸ್ತ್ರಚಿಕಿತ್ಸೆ ಹೊಂದಿರುವ, ಹೊಂದಿದ್ದ, ಅಥವಾ ಭವಿಷ್ಯದಲ್ಲಿ ಹೊಂದಬಹುದನ್ನು ತೋರಿಸಬಹುದು.

(3) ಲೇಖನವನ್ನು ಪ್ರಪಂಚದಾದ್ಯಂತ ವಿತರಿಸಲಾಗುವ ಜರ್ನಲ್‌ನಲ್ಲಿ ಪ್ರಕಟಿಸಬಹುದು. BMJ ನ ಪ್ರಕಟಣೆಗಳು ಮುಖ್ಯವಾಗಿ ವೈದ್ಯರು ಮತ್ತು ಇತರ ಆರೋಗ್ಯ ವೃತ್ತಿಪರರಿಗೆ ಹೋಗುತ್ತವೆ. ಆದರೆ, ಶಿಕ್ಷಣ ತಜ್ಞರು, ವಿದ್ಯಾರ್ಥಿಗಳು ಮತ್ತು ಪತ್ರಕರ್ತರು ಸೇರಿದಂತೆ ಅನೇಕರು ನೋಡುತ್ತಾರೆ.

(4) ವಸ್ತು ಸೇರಿದಂತೆ ಲೇಖನವು, ಪತ್ರಿಕಾ ಪ್ರಕಟಣೆಯ ವಿಷಯವಾಗಿರಬಹುದು ಮತ್ತು ಸಾಮಾಜಿಕ ಮಾಧ್ಯಮದಲ್ಲಿ ಲಿಂಕ್ ಮಾಡಬಹುದು ಮತ್ತು/ಅಥವಾ ಇತರ ಪ್ರಚಾರ ಚಟುವಟಿಕೆಗಳಲ್ಲಿ ಬಳಸಲಾಗುತ್ತದೆ. ಪ್ರಕಟಿಸಿದ ನಂತರ, ಲೇಖನವನ್ನು BMJ ವೆಬ್‌ಸೈಟ್‌ನಲ್ಲಿ ಇರಿಸಲಾಗುತ್ತದೆ ಮತ್ತು ಇತರ ವೆಬ್‌ಸೈಟ್‌ಗಳಲ್ಲಿಯೂ ಲಭ್ಯವಿರಬಹುದು.

(5) ಲೇಖನದ ಪಠ್ಯವನ್ನು ಪ್ರಕಟಣೆಯ ಮೊದಲು ಶೈಲಿ, ವ್ಯಾಕರಣ ಮತ್ತು ಸ್ಪಷ್ಟತೆಗಾಗಿ ಸಂಪಾದಿಸಲಾಗುತ್ತದೆ.

(6) ನಾನು/ರೋಗಿಯು ಲೇಖನದ ಪ್ರಕಟಣೆಯಿಂದ ಯಾವುದೇ ಹಣಕಾಸಿನ ಪ್ರಯೋಜನವನ್ನು ಪಡೆಯುವುದಿಲ್ಲ.

(7) BMJ ಮತ್ತು/ಅಥವಾ ಇತರ ಪ್ರಕಾಶಕರು ಪ್ರಕಟಿಸುವಂತಹ ಇತರ ಪ್ರಕಟಣೆಗಳು ಮತ್ತು ಉತ್ಪನ್ನಗಳಲ್ಲಿ ಈ ಲೇಖನವನ್ನು ಪೂರ್ಣವಾಗಿ ಅಥವಾ ಭಾಗಶಃ ಬಳಸಬಹುದು. ಇದು ಇಂಗ್ಲಿಷ್‌ನಲ್ಲಿ ಮತ್ತು ಅನುವಾದದಲ್ಲಿ ಮುದ್ರಣ ರೂಪದಲ್ಲಿ, ಡಿಜಿಟಲ್ ಫಾರ್ಮಾಟ್‌ಗಳಲ್ಲಿ ಮತ್ತು BMJ ಅಥವಾ ಇತರ ಪ್ರಕಾಶಕರು ಪ್ರಸ್ತುತ ಬಳಸುತ್ತಿರುವಂತಹ ಮತ್ತು ಭವಿಷ್ಯದಲ್ಲಿ ಬಳಸಬಹುದಾದ ಯಾವುದೇ ಇತರ ಸ್ವರೂಪಗಳಲ್ಲಿಯೂ ಪ್ರಕಟಿಸುವುದನ್ನು

ರೋಗಿಯ ಒಪ್ಪಿಗೆ ನಮೂನೆ 01/01/19





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BMJ

ಒಳಗೊಂಡಿರುತ್ತದೆ. ಲೇಖನವು UK ಮತ್ತು ವಿದೇಶದಲ್ಲಿ ಪ್ರಕಟವಾಗುವಂತಹ ನಿಯತಕಾಲಿಕಗಳ ಸ್ಥಳೀಯ ಅಭಿಪ್ರಾಯಗಳಲ್ಲಿ ಅಥವಾ ಇತರ ಪ್ರಕಟಣೆಗಳಲ್ಲಿಯೂ ಕಾಣಿಸಿಕೊಳ್ಳಬಹುದು."

(8) ಪ್ರಕಟಣೆಯ ಮೊದಲು ನಾನು ಯಾವುದೇ ಸಮಯದಲ್ಲಿ ನನ್ನ ಸಮ್ಮತಿಯನ್ನು ಹಿಂಪಡೆಯಬಹುದು, ಆದರೆ ಒಮ್ಮೆ ಲೇಖನವನ್ನು ಪ್ರಕಟಗೊಳಿಸಲು ಕಾರ್ಯಗತಗೊಳಿಸಿದರೆ ("ಮುದ್ರಣಕ್ಕೆ ಹೋದಲ್ಲಿ") ಒಪ್ಪಿಗೆಯನ್ನು ಹಿಂಪಡೆಯಲು ಸಾಧ್ಯವಾಗುವುದಿಲ್ಲ.

(9) ಈ ಸಮ್ಮತಿಯು ನಮೂನೆಯನ್ನು ಕಾನೂನಿಗೆ ಅನುಸಾರವಾಗಿ BMJ ಸುರಕ್ಷಿತವಾಗಿ ಮತ್ತು ವಿಶ್ವಾಸದಿಂದ, ಅಗತ್ಯವಿರುವಷ್ಟು ಕಾಲ ಉಳಿಸಿಕೊಳ್ಳುತ್ತದೆ. <https://www.bmj.com/company/your-privacy/> ನಲ್ಲಿ ಲಭ್ಯವಿರುವ BMJ ನ ಗೌಪ್ಯತಾ ನೀತಿಗೆ ಅನುಗುಣವಾಗಿ ಈ ಫಾರ್ಮ್ ನಲ್ಲಿ ಒದಗಿಸಲಾದ ವೈಯಕ್ತಿಕ ಡೇಟಾವನ್ನು ಬಳಸಲಾಗುತ್ತದೆ ಮತ್ತು ಉಳಿಸಿಕೊಳ್ಳಲಾಗುತ್ತದೆ.

ಕೆಳಗಿನವುಗಳನ್ನು ಖಚಿತಪಡಿಸಲು ದಯವಿಟ್ಟು ಬಾಕ್ಸ್ ಟಿಕ್ ಮಾಡಿ :

☐ ಈ ಸಮ್ಮತಿಯು BMJ ಕೆಫ್ ವರದಿಗಳಲ್ಲಿನ ಲೇಖನಕ್ಕೆ ಸಂಬಂಧಿಸಿದೆ, ನನ್ನ ಬಳಿ/ರೋಗಿಯ ಬಳಿ ಲೇಖನದ ಕುರಿತು ಕಾಮೆಂಟ್ ಮಾಡಲು ಅವಕಾಶವಿದೆ ಮತ್ತು ಲೇಖನದಲ್ಲಿ ಯಾವುದಾದರೂ ಕಾಮೆಂಟ್‌ಗಳು ಪ್ರತಿಫಲಿಸುತ್ತಿದ್ದರೆ, ನಾನು ತ್ಯಜಿಸುತ್ತೇನೆ.

ಸಹಿ ಮಾಡಲಾಗಿದೆ: ಮುದ್ರಣ ಮುದ್ರಣ ಹೆಸರು: _____

ವಿಕಾಸ: _____ ಇಮೇಲ್ ವಿಳಾಸ: _____

ದೂರವಾಣಿ ಸಂಖ್ಯೆ: _____

ರೋಗಿಯ ಪರವಾಗಿ ಸಹಿ ಮಾಡುತ್ತಿದ್ದರೆ, ರೋಗಿಯು ಸ್ವತಃ ಏಕೆ ಒಪ್ಪುತ್ತಿದ್ದರೂ ಎಂಬ ಕಾರಣವನ್ನು ನೀಡಿ (ಉದಾ. ರೋಗಿಯು 18 ವರ್ಷದೊಳಗಿನವರು ಅಥವಾ ಅರಿವಿನ ಅಥವಾ ಬೌದ್ಧಿಕ ಮರ್ಬಲತೆಯನ್ನು ಹೊಂದಿದ್ದಾರೆ).

patient is under 18 ದಿನಾಂಕ: 18/06/24

☐ ನೀವು ಕುಟುಂಬ ಅಥವಾ ಇತರ ಗುಂಪಿಗೆ ಸಹಿ ಮಾಡುತ್ತಿದ್ದರೆ, ಕುಟುಂಬದ ಎಲ್ಲಾ ಸಂಬಂಧಿತ ಸದಸ್ಯರು ಅಥವಾ ಗುಂಪಿಗೆ ತಿಳಿಸಲಾಗಿದ ಎಂಬುದನ್ನು ಖಚಿತಪಡಿಸಲು ಬಾಕ್ಸ್ ಅನ್ನು ಟಿಕ್ ಮಾಡಿ.

ರೋಗಿಯು 18 ವರ್ಷಕ್ಕಿಂತ ಕಡಿಮೆ ವಯಸ್ಸಿನವರಾಗಿದ್ದರೆ, ಒಪ್ಪಿಗೆ ಪ್ರಕ್ರಿಯೆ ಮತ್ತು ಅದರ ಪರಿಣಾಮಗಳ ಬಗ್ಗೆ ಸಾಕಷ್ಟು ತಿಳುವಳಿಕೆಯನ್ನು ಹೊಂದಿದ್ದರೆ, ಅವರು ತಮ್ಮ ಒಪ್ಪಂದವನ್ನು ಸಹ ದೃಢೀಕರಿಸಬೇಕು:

ಸಹಿ ಮಾಡಲಾಗಿದೆ: _____ ಮುದ್ರಣ ಹೆಸರು: _____

ಹುಟ್ಟಿದ ದಿನಾಂಕ: _____ ದಿನಾಂಕ: _____

ರೋಗಿಗೆ ಅಥವಾ ಅವರ ಪ್ರತಿನಿಧಿಗೆ ಫಾರ್ಮ್ ಅನ್ನು ವಿವರಿಸಿದ ಮತ್ತು ನಿರ್ವಹಿಸಿದ ವ್ಯಕ್ತಿಯ ವಿವರಗಳು (ಉದಾ. ಅನುಗುಣವಾದ ಲೇಖಕ ಅಥವಾ ಸಮ್ಮತಿಯನ್ನು ಪಡೆಯುವ ಅಧಿಕಾರ ಹೊಂದಿರುವ ಇತರ ವ್ಯಕ್ತಿ).

ಸಹಿ ಮಾಡಲಾಗಿದೆ: Stephy Angel M ಮುದ್ರಣ ಹೆಸರು: Ms. Stephy Angel M

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ರೋಗಿಯು 18 ವರ್ಷದೊಳಗಿನವರು 0204/18





Performance Evaluation of Numerical Estimation Methods to Obtain the Weibull Parameter in Wind Energy Assessment in Kolkata City

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ABSTRACT

Wind energy has been considered as a significant contributor of renewable energy, underscoring the necessity of evaluating its potential. The Weibull distribution is frequently employed for this objective. This study evaluates the efficacy of the probability-weighted moment utilising the power density method (PWM) against three recognised numerical techniques for ascertaining Weibull parameters. The analysis utilises daily average wind speed data from Kolkata City over five years (2012-2016). The results demonstrate that the Moment method has the least error, succeeded by the Probability Weighted Moment utilising the power density approach. This indicates that the precision and efficacy of numerical estimating techniques for deriving Weibull parameters are contingent upon the dataset utilised, which is influenced by the meteorological conditions and surface attributes, including roughness and orography, of the chosen region.

Keywords: Weibull parameters, Wind speed, Numerical method, Probability weighted moment method.





INTRODUCTION

Renewable energy has become essential in combating the risks of global warming, mostly caused by substantial carbon dioxide emissions resulting from fossil fuels. Wind energy has emerged as the preeminent form of renewable energy. If the current trend persists, by 2030, the global cumulative installed wind power capacity may attain 2110 GW, resulting in a reduction of carbon dioxide emissions by at least 3300 million tonnes per year [1]. Nonetheless, wind is stochastic, hence the utilisation of wind energy encompasses three critical phases. The initial and important phase is the assessment of its resources at a designated site, followed by the production and installation of wind turbines. Numerous statistical approaches exist for evaluating wind resources, including Normal, Lognormal, Exponential, Gamma, Inverse Gaussian, Rayleigh, Nakagami, and Weibull distributions, among others. The precision of the study is contingent upon the parameters associated with any distribution method. Graphical (GM), Moment method (MM), Maximum likelihood (ML), Modified maximum likelihood (MML), Empirical (EM), and Equivalent energy (EE) methods are traditional numerical techniques for estimating parameters in statistical distributions. Consequently, this study evaluates several widely recognised numerical approaches utilising the daily mean speed data from Kolkata City for the five-year period of 2012-2016, obtained from the Regional Meteorological Centre, Kolkata. The specific topographic coordinates of the chosen place are presented in Table 1.

LITERATURE REVIEW

A comprehensive survey indicates that numerous academics have evaluated the efficacy of different statistical distributions, concluding that the Weibull distribution is the most reliable and effective way for assessing the energy resources. Wang et al. [2] assessed six distinct statistical distributions and demonstrated that the Weibull distribution approach surpasses all others. Alavi et al. [3] assessed the efficacy of 8(eight) distinct methods of statistical distribution and determined that the Weibull and Nakagami distributions are 2(two) versatile and successful approaches to analyse the data. Likewise, numerous studies [4-8] evaluated the efficacy of Weibull and Rayleigh distribution methods, concluding that the former is the most frequently endorsed distribution method for wind energy resource assessment. Consequently, this study will employ the Weibull distribution approach. Precision of Weibull distribution depends on the estimated values of its parameters. Multiple estimating approaches can be employed to derive Weibull parameters from a specific collection of wind data. The choice of the optimal approach is a crucial prerequisite for obtaining precise Weibull parameter values. Consequently, numerous prior studies examined and assessed the efficacy of various numerical estimate techniques. Azad et al. [9] assessed the efficacy of four approaches and concluded that the moment method yields the minimal error among them. Akdag and Dinler [10] evaluated traditional estimators, including GM, ML, and MM, and then proposed a novel technique called the power density method (PD). The researchers determined that the PD approach served as an excellent alternative estimator. Chang [11] assessed six traditional estimators for deriving Weibull parameters over three locations in Taiwan. He evaluated the efficacy of all six estimators via Monte Carlo simulation and determined that the ML approach was superior, succeeded by the MML and MM methods. Rocha et al. [12] assessed the efficacy of seven numerical estimators and determined that the equivalent energy technique was the most successful for deriving Weibull parameters in the specified region of Brazil. Genc et al. [13] assessed and contrasted the efficacy of least squares (LS), maximum likelihood (ML), and method of moments (MM) techniques in evaluating the potential of wind energy in a region of Turkey. The Monte Carlo simulation was utilised to evaluate the efficacy of several strategies, revealing that MM was the most successful, whereas the LS method exhibited the poorest performance. Likewise, other publications evaluated the efficacy of various numerical approaches, revealing that the maximum likelihood method, the power density method, or both were deemed effective and precise for predicting Weibull parameters [14-20]. Usta [21] introduced a novel technique termed probability-weighted moment, derived from the power density method (PWM), and evaluated its efficacy against GM, MM, ML, MML, and PD methodologies. The proposed method demonstrates superior performance compared to all alternative methods. The aforementioned approaches are consistently employed for wind energy resource assessment, with the exception of PWM.





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Consequently, this study will reassess the efficacy of PWM and juxtapose it with three highly recognised methodologies: MM, ML, and PD approaches. The authors of this research already assessed the efficacy of well recognised numerical methods while evaluating its feasibility of wind power generation for the North-eastern region of India in their earlier works [22, 23].

Weibull parameters estimation methods

The two-parameter Weibull distribution is characterised by its cumulative distribution function and the probability density function, which is shown below:

$$F(v) = 1 - e^{-(v/l)^p} \quad (1)$$

$$f(v) = \frac{dF(v)}{dv} = \left(\frac{pv^{p-1}}{l^p} \right) e^{-(v/l)^p} \quad (2)$$

Where l = scale parameters (m/s), v is wind speed in m/s and p is the shape parameter.

Herein are illustrated the numerical approaches for estimating the shape and scale parameters of the Weibull distribution:

Moment method (MM)

The form and size parameters [9] can be articulated in relation to the known mean wind speed and the standard deviation of wind speeds, as delineated in Eq. (3) and Eq. (4):

$$p = (0.9874 \bar{v} / \sigma)^{1.0983} \quad (3)$$

$$l = \bar{v} / \Gamma(1 + 1/p) \quad (4)$$

Maximum likelihood method (ML)

This is an iterative estimating method introduced by Stevens and Smulders for wind energy applications [11, 17-19], represented by Eq. (5) and Eq. (6):

$$p = \left[\frac{\sum_{i=1}^n v_i^p \ln(v_i)}{\sum_{i=1}^n v_i^p} - \frac{\sum_{i=1}^n \ln(v_i)}{n} \right]^{-1} \quad (5)$$

$$l = \left[\frac{\sum_{i=1}^n (v_i)^p}{n} \right]^{1/p} \quad (6)$$

Power density method (PD)

Akdag and Dinler [10] introduced it to estimate the shape parameter using a new term called energy pattern factor (E_f) which is equal to $\overline{v^3} / (\bar{v})^3$ and then Eq. (7) gives " p " term.

$$p = 1 + \frac{3.69}{(E_f)^2} \quad (7)$$

The expression for l the "parameter is given in Eq. (4), which is expressed under the moment method.



**Probability weighted moment based on power density (PWM)**

This numerical model was first introduced by Usta [21] to determine “ p ” and “ l ” terms for the wind energy resource evaluation whose model are represented by the following Eq. (8) and Eq. (9):

$$p = \frac{\ln(2)}{\ln\left(\frac{\bar{v}}{(2/(n^2 - n)) \sum_{i=1}^n v_{(i)}(n-i)}\right)} \quad (8)$$

$$l = \sqrt[3]{\frac{\bar{v}^3}{\Gamma(1 + 3/p)}} \quad (9)$$

Wind power density (WPD)

The power potential/unit area, referred as the power density, can be articulated using Weibull parameters as demonstrated in Eq. (10) to evaluate the overall efficacy of the chosen estimating methods [4, 15].

$$P = 0.5 \rho \int_0^\infty v^3 f(v) dv = 0.5 \rho l^3 \Gamma(1 + 3/p) \quad (10)$$

Performance analysis

To assess and compare the efficacy of the four chosen approaches, the three standard performance metrics—root mean square error (RMSE), coefficient of determination (R^2), and power density error (PDE) are utilised, as depicted in Table 2.

RESULTS AND DISCUSSION

The seasonal mean wind speed variation for 5(five) years is represented in the Fig 1 below, and it reveals that mean wind speed range in the summer is higher than the remaining seasons, while the lowest range is found during the winter. The wind speed has increased between 2012 and 2016, according to these changes in the data collected year by year. Figure 2-5 represents the histogram, Weibull probability density, and cumulative distribution functions for winter, summer, monsoon, and annual collected wind data. It shows that more than 90% of data falls within the range of 0.5 to 3.5 m/s. The functions for all methods except the power density method (PD) show similar behavior and conform to the actual wind speed profile. Table 2 presents the Weibull parameters and performance assessment of all four methodologies. Except for the PD method, all of the other approaches have consistent values for shape & scale parameters as shown in the table 2 below. The data suggests that the scale parameter is elevated in summer, signifying greater wind power potential during this season, whereas the winter exhibits the lowest wind power potential. Above figures reveal that the value corresponding to the PD method is very much closer to the actual value. Regarding seasonal variation, summer provides the maximum WPD while winter provides the minimum WPD, whose values based on actual wind speed are 32.05 W/m² and 4.58 W/m², respectively. At the same time, the annual average actual WPD is 17.45 W/m², and unsuitable for the generation of high power. Hence, Vertical Axis Wind Turbine (VAWT) may be deployed to harness the maximum possible power from wind energy resources. Moreover, Table 2 and Fig.6 show that the seasonal variation of WPD is analogous to the seasonal variation of Weibull parameters, ultimately validating the nature of the Weibull distribution. Regarding the performance of the selected numerical methods, the RMSE value of the PWM method is the lowest in all seasons except during summer, followed by the moment method. The R^2 value of the moment method is the largest in all seasons, followed by maximum likelihood. The power density technique has the lowest PDE value across all seasons, followed by the method of moment and maximum likelihood.





CONCLUSIONS

The moment methodology outperforms all other methods, according to the analysis of the used wind speed data for Kolkata City. The probability-weighted moment based on the power density method comes in second. The accuracy and effectiveness of the estimation techniques for the Weibull distribution model's shape and scale parameters depend on the dataset used, which is impacted by the local climate and surface features, such as the location's roughness and orography. Based on actual wind speed, the annual average wind power density is 17.45 W/m², which makes it insufficient for large-scale power production. In these situations, the best wind energy may be captured by using VAWT. However, wind power density (WPD) will be increased by extrapolating wind speed measurements through an elevation of the anemometer.

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Table 1. Topographic data of the selected location

Location	Latitude (N)	Longitude (E)	Elevation (m)	Anemometer height (m)
Kolkata	22°32'	88°20'	6.4	17.01

Table 2. Wind characteristics and statistical performance

Season	Methods	p	l	Performance criteria		
				RMSE	R ²	PDE
Winter	MM	1.970	1.578	0.0228	0.9596	0.4218
	PD	4.122	1.541	0.0379	0.8181	-0.1046
	ML	1.999	1.583	0.0228	0.9582	0.4134
	PWM	2.003	1.598	0.0226	0.9559	0.4492
Summer	MM	2.245	3.305	0.0155	0.9832	0.6444
	PD	3.990	3.229	0.0257	0.9514	0.1838
	ML	2.266	3.315	0.0157	0.9828	0.6476
	PWM	2.251	3.321	0.0156	0.9826	0.6655
Monsoon	MM	1.923	2.472	0.0123	0.9707	0.5772
	PD	4.132	2.414	0.0223	0.9355	-0.0320
	ML	1.948	2.482	0.0123	0.9698	0.5743
	PWM	1.963	2.515	0.0122	0.9669	0.6238
Annual	MM	1.782	2.457	0.0085	0.9659	0.5850
	PD	4.154	2.407	0.0163	0.9659	-0.1062
	ML	1.818	2.470	0.0085	0.9647	0.5699
	PWM	1.811	2.497	0.0084	0.9621	0.6289



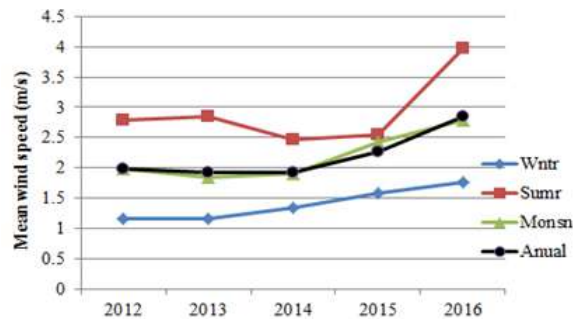
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Fig.1. Mean wind speed of various seasons for five years

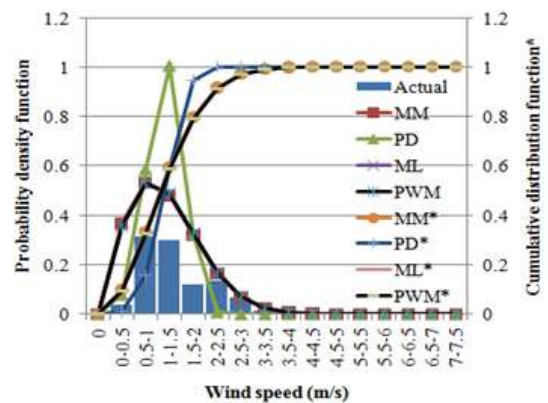


Fig.2. Weibull functions of winter data

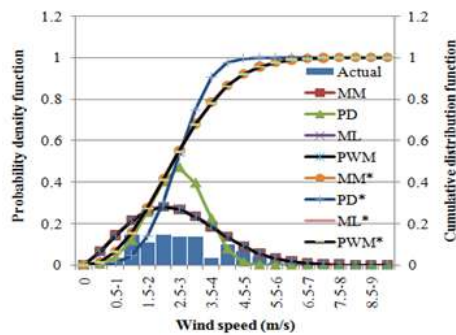


Fig.3. Weibull functions of summer data

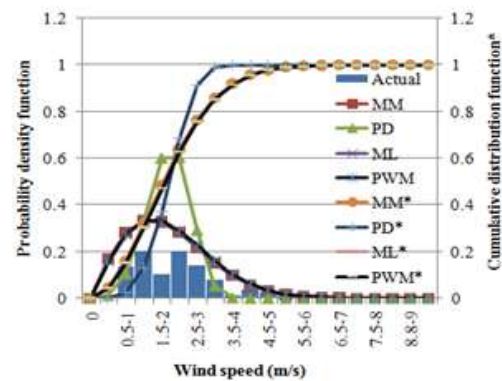


Fig.4. Weibull functions of monsoon data

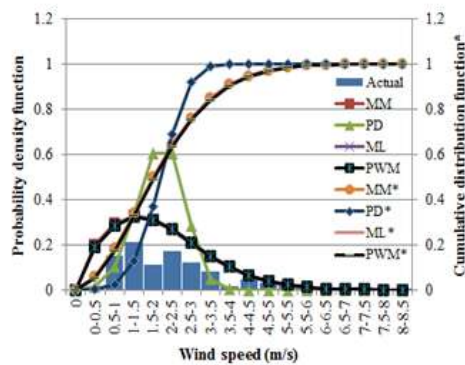


Fig.5. Annual Weibull functions

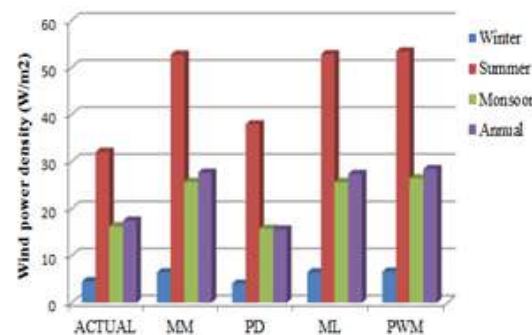


Fig.6. Comparison of seasonal wind power density obtained by four different numerical estimation procedures





RESEARCH ARTICLE

A Bibliometric Analysis of Fintech with Reference to Digital Payment: An Empirical Investigation

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ABSTRACT

For more than a decade, scholars, students, and institutions throughout the world have been interested in financial technology. With a wealth of new financial services, products, and novel ways to communicate with prospects, the effect of technology on the financial industry has been thoroughly researched. This study paper uses a bibliometric approach to present a summary of FinTech research with a focus on Digital Payment Platforms. Using the Open Alexdatabases, the report examined 1559 articles from 2020 to 2024 and identified research gaps and novel study using "VOS-Viewer" software. The study examined the relationships between the most significant papers to determine FinTech's functions and research limits in digital finance and payment. The findings serve as a foundation for further exploration and provide opportunity for scholars to broaden their knowledge in intriguing and novel investigations. Overall, the goal of this study is to assist scholars in discovering new lines of discovery in Fintech while also expanding their current expertise.

Keywords: Fintech, Digital Payment, Cryptocurrencies, Bibliometric Analysis, VOS viewer, AI

INTRODUCTION

The term "fintech," which combines the terms "finance" and "technology," was first used by banks to refer to technology that assisted them in monitoring and managing the accounts of their customers. But over the past five years, the phrase has changed to encompass more consumer-related services, such software and applications for tracking expenses, making budgets, and buying and selling stocks. (**What is fintech?, 2024**)[1] Bibliometric analysis is





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a widely used and robust approach for examining extensive scientific data. It uncovers the developmental trends of a field and highlights emerging areas, though its use in business research remains relatively recent and often underutilized. (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021)[2]

LITERATURE REVIEW

(Garg & et al, 2023)[3] In this study, the researchers establish a foundation for the development of Fintech gain popularity during the last decade, and various research have been published utilizing this methodology. It aids in understanding key variables in any given study topic. In this study, they identified notable authors and nations using citation and co-citation analyses of FinTech research. (Mohammad Sahabuddin, 2023)[4] The purpose of this study is to use bibliometric analysis to evaluate how FinTech research changed over time. First, 1359 papers specifically linked to FinTech were extracted from the Scopus repository between 2010 and 2021. This study investigated the essential issues and features of FinTech in research, such as the yearly contribution of publishing, hot in the press, and focuses, using topic analysis, concurrence analysis, and chronology analysis of contributors' keywords. (Bajwa, Rehman, & Iqbal, 2022)[5] This study conducted a meta-literature review of 360 selected publications published between 2006 and June 2020 to examine the history, present, and potential future trends in Fintech research. The quantitative technique involved a bibliometric citation analysis using HistCite and VOS viewer software, while the qualitative analysis (Brika, 2021)[6] The study examines how financial technologies are organized. The study is focused on the functions of Fintech and the limitations of research in digital financing. They identify potential paths for researchers to explore in order to expand on current knowledge while also identifying opportunities for innovative, fascinating, and creative research that contributes to the extension of the area of study. (Zou, Xindi Liu, Xindi Liu, & Xinze Yang, 2023)[7] Digital finance, a rapidly growing financial model, is analysed in this study using 1,191 documents (2006–2022) from Web of Science and Scopus. Employing bibliometric and content analysis, it examines publication trends, key contributors, and citation networks comprehensively.

RESEARCH METHODOLOGY

Data Collection

Data Sources: The Scopus and Web of Science (WoS) databases are the primary data sources, as they are widely recognized for their comprehensive coverage of peer-reviewed academic literature. 1159 articles from the year 2020-2024 studied from Open Alex.

Search Strategy: The search query includes a combination of keywords such as "Fintech," "digital payment," "financial technology," "blockchain in payments," and "mobile payments."

METHODOLOGY

This study adopts a bibliometric analysis approach to explore the domain of financial technology (Fintech) with a specific focus on digital payments. Bibliometric analysis is a quantitative research technique used to systematically analyze academic literature and reveal patterns, trends, and insights in the field. The research design includes data collection, data cleaning, and bibliometric techniques such as citation analysis, co-citation analysis, and keyword co-occurrence analysis.

Tools and Software

VOSviewer: For constructing and visualizing bibliometric networks (e.g., co-authorship, cocitation)

Microsoft Excel: For data cleaning and descriptive statistics.

OBJECTIVES

- To determine which country undertakes the most research in the Fintech domain.
- Find the most prominent authors in the Fintech area.





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- Identify key words wise trend.

RESULT ANALYSIS AND INTERPRETATION:

Year wise Publication

The field of Fintech and digital payments has experienced significant growth, with a peak in 2023. The 2024 dip requires further investigation, as it could indicate either incomplete data or a potential levelling off of research activity. The steady increase from 2020 highlights the increasing importance of digital payments and the ongoing innovation in Fintech.

Country Wise Publication

Countries at the centre of the network with numerous connections are likely the leading contributors to Fintech research. The United States, known for its leadership in technological innovation and financial systems. China, which has a robust digital payment ecosystem and significant Fintech advancements. European countries such as the United Kingdom and Germany, which have strong academic and financial sectors. Indonesia is having the 364 papers but less in terms of citation so the strength is less than the US.

Affiliation wise Contribution

The table indicates notable contributions to Fintech research by institutions globally. The University of Indonesia and Universiti Teknologi MARA lead with the highest number of publications (15 each), showcasing their dominance in this field. Binus University, University of London, University of Malaya, and Padjadjaran University each contributed significantly, with 10-12 publications. Renowned global institutions like the International Monetary Fund (9) and Durham University (8) highlight the international collaboration in Fintech research. Universities across Asia, such as Northern University of Malaysia and Islamic University College, also show robust engagement, reflecting the growing prominence of Fintech in developing economies.

Key Words

Researchers conducted a co-occurrence analysis utilizing the author keywords and identified eight primary clusters of FinTech literature, as shown in Figure 4. A total of 200 key phrases were found, with 11955 links followed by 121650 link strength. Fintech, Financial System, Computer Science, Economics, Financial Services, Payments, Trade, and Accounting. The keywords network can help researchers find research gaps. There is still a lot to learn about digital loans, supply chain finance, the internet of things, and Robo advisers. Keyword network diagrams aid researchers in discovering untapped study areas.

LIMITATIONS

This study emphasizes FinTech applications in business, finance, and insurance, excluding research from multidisciplinary journals. For analysis, we utilized VOSviewer for co-citation, co-occurrence, and network diagrams, despite the availability of various other analytical software tools.

IMPLICATIONS

Bibliometric analysis is a quantitative approach for examining publication trends, citations, and collaborations in scientific literature. It assesses research impact, identifies influential studies and researchers, and reveals trends in scientific fields. Useful for policymakers, funding agencies, and researchers, it aids in making informed decisions on research priorities. Additionally, it analyzes collaboration networks, measures productivity, and highlights underexplored areas or conflicting findings within research fields.





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CONCLUSION

In conclusion, this study highlights the growing interest in FinTech, particularly in digital payment platforms, through a comprehensive bibliometric analysis. By examining key research trends, gaps, and relationships in the field, it provides valuable insights for scholars and institutions to expand their understanding and explore emerging avenues in FinTech research.

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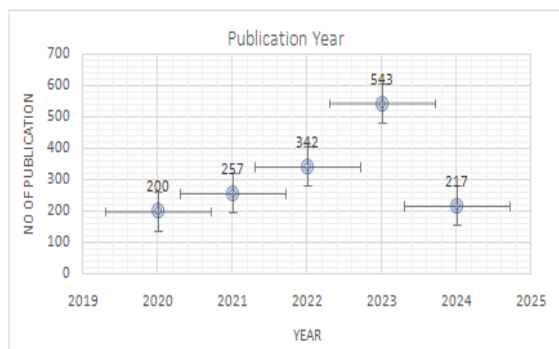


Figure 1. Documents Year Wise. Source: Author's Contribution

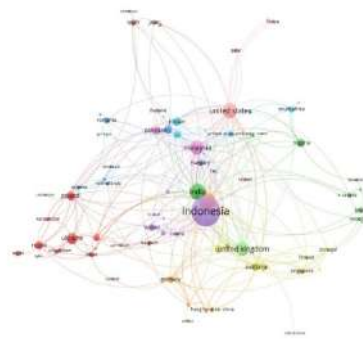


Figure 2. Country wise. Source: Author's Contribution using VOS Viewer



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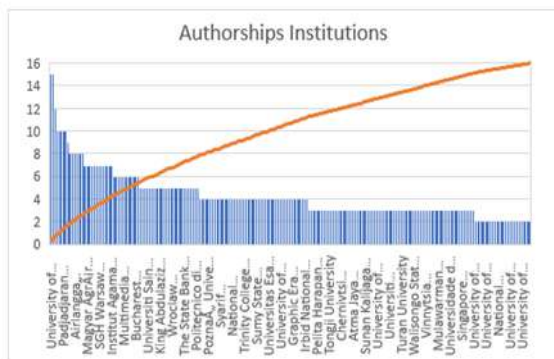


Figure 3. Documents Affiliation. Source: Author's Contribution

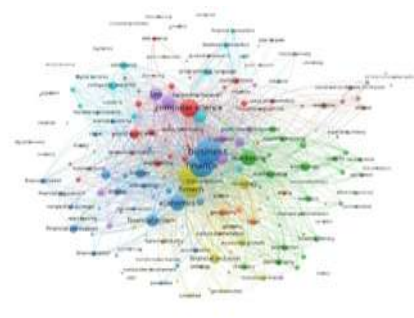


Figure 4. Key Words. Source: Author's Contribution





A Cryptographic Technique Utilizing Trigonometric Ratios Enhanced by Hankel Transformation

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ABSTRACT

In this study, researcher explored a novel cryptographic approach based on a trigonometric ratio utilizing the Hankel transform. We employed the Hankel transform as a means to convert plain text into cipher text for the secure exchange of data. In this paper modular arithmetic is utilized in the decryption process, along with the concept of congruence for data evaluation.

Keywords: Hankel Transform, Cryptography, Encryption, Decryption, Modulo.

INTRODUCTION

Keeping data safe from the people who are not supposed to see it or to communicate secretly with selective recipient is really important. Cryptography plays a pivotal role in securing data. Cryptography is an art of secret coding for confidentiality. In cryptography the original data is locked by using some secret keys to scramble it so that it cannot be read by anyone who doesn't know the secret keys. The scrambled message is then transferred to recipient. The recipient use the same secret key to unscramble the data and read the data. The process of scramble up the data using secret key is called encryption, and the process of unscramble the data is called decryption.

Cryptosystem

Various method has been developed and employed to encrypting the data. In 2012, Hiwarekar A P[1], Uses the method of laplace transform for encryption of the original text and then apply inverse laplace transform on the cipher text for decryption. Original text also known as Plain text, by choosing an specific type of secret key and application of Laplace transform Plain text is converted into an unreadable text known as cipher text, this process is called





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encryption. The cipher text contains all the details of plain text but is not understandable unless an decryption is done, which is done in reverse order of encryption. Here the secret key plays a vital role, the encryption process varied on the choice of this key. In 2014, Gupta P & Mishra PR [2], Concluded that it is an weak strategy as encryption is independent of Laplace Transform and cipher text can be decrypted using any algebraic algorithm., In 2017, Tyagi N, Agrawal A, Katiyar A, Garg S & Yadav S [3], Worked on updating and modifying the contemporary methods. In 2013, Hiwarekar A P[4], Develop a new cryptographic method using laplace transform of hyperbolic function. In 2021, JadhavShailaShivaji, HiwarekarAP[5], Uses Elzaki and laplace transform for encryption, inverse Elzaki and inverse laplace transform for decryption to develop new method of cryptography, they also apply iteration that added in additional security. In 2022[6], cryptographic algorithm using Type IVa MP-Wavelets is proposed and it is concluded that this algorithm has good performance and fast computation rate. In 2020, Hemant K. Undegaonkar, R. N. Ingle[7], Applied Laplace transform & Sumudu transform for encryption & decryption. On Applying both transforms for the same plain text to the same function results in the same cipher text but applying both transforms to different functions gives different cipher texts for the same plain text. In 2021, Mohammed N. Alenezi and Fawaz S. Al-Anzi [8], form an algorithm for encryption using Z- transformation and XOR function. In 2020, [9], it is concluded that it is very critical to secure wireless network through encryption and cryptography by the techniques viz, digital signature, watermarking and steganography while addressing encroachment and computer protection technologies.

PRELIMINARIES

Definition 2.1.

The Hankel transform of the function $f(x)$, $-\infty < x < \infty$, is defined as

$$H_n\{f(x)\} = \widehat{f(s)} = \int_{-\infty}^{\infty} f(x) \cdot x J_n(sx) dx$$

Where $J_n(sx)$ is the Bessel function of the first kind of order n .

As a result of above formula we have,

$$H_n\{r^{s-1}\} = \frac{2^s \Gamma\left[\frac{s+1}{2}\right]}{\rho^{s+1} \Gamma\left[\frac{1-s}{2}\right]} \text{ where, } |s| > 1$$

Definition 2.2.

Linearity property of Hankel transform

$$H_n\{C_1 f(r) + C_2 g(r)\} = C_1 H_n\{f(r)\} + C_2 H_n\{g(r)\}$$

Numerical Assignment of Letters

Space	A	B	...	Y	Z
0	1	2		25	26

Encryption Algorithm

Step 1: The sender and recipient have concurred on the encryption key.

Step 2: The series explore to address the issue is:

$$\alpha^n \sin \alpha x = \alpha^n \left[\alpha x - \frac{(\alpha x)^3}{3!} + \frac{(\alpha x)^5}{5!} - \frac{(\alpha x)^7}{7!} + \dots \right] = \sum_{i=0}^{\infty} \frac{(-1)^i (\alpha)^{2i+1} (\alpha)^{2i+n+1}}{(2i+1)!}$$

Where $\alpha, n \in \mathbb{N}$ are constants

Step 3: Assigned numerical values to letters to ascertain corresponding plaintext. Depict each term as P_i ; $i \geq 0$.

Step 4: Each P_i is regarded as the coefficient of $\alpha^n \sin \alpha x$.

Step 5: Take into account the quantity of terms in the series equivalent to the number of P_i obtained.

Step 6: For P_n ; $n = 2i + 1$; $i \geq 0$; Translate this into its equivalent expression Q_n employing $P_n \equiv Q_n \pmod{27}$.

Step 7: Find Hankel transform of the given series employing $H_n\{r^{s-1}\} = \frac{2^s \Gamma\left[\frac{s+1}{2}\right]}{\rho^{s+1} \Gamma\left[\frac{1-s}{2}\right]}$.





Step 8: If the resulting coefficient is greater than or equals to 25 then they are resolved by employing congruence relation as $x \equiv y \pmod{n}$.

Step 9: The sender transmits the values that are quotients in the modulo operation as a key.

Step 10: If any terms in the final key are 26 or greater, employ congruence relations to determine the cipher text. Express the components of the cipher text as l_i .

Decryption Algorithm

Step 1:

$$H \left[\sum_{i=0}^{\infty} \frac{a^{2i+1} \alpha^{2i+n+1} (-1)^i P_i}{(2i+1)!} \right] \\ = H \left[\sum_{i=0,2,4,\dots}^{\infty} \frac{a^{2i+1} \alpha^{2i+n+1} P_i}{(2i+1)!} \right] + H \left[\sum_{i=1,3,5,\dots}^{\infty} \frac{a^{2i+1} \alpha^{2i+n+1} Q_i}{(2i+1)!} \right]; Q_i = -P_i \\ = \left[\sum_{i=0,2,4,\dots}^{\infty} \frac{a^{2i+1}}{(2i+1)!} \frac{2^{n+1} \left[\frac{n+1}{2} \right]^2 P_i}{\rho^{n+2}} \right] + \left[\sum_{i=1,3,5,\dots}^{\infty} \frac{a^{2i+1}}{(2i+1)!} \frac{2^{n+1} \left[\frac{n+1}{2} \right]^2 Q_i}{\rho^{n+2}} \right]$$

Step 2: If each $P_i \leq 26$

Find

$$\frac{a^{2i+1}}{(2i+1)!} 2^{n+1} \left[\frac{n+1}{2} \right]^2 P_i = 26k_i + l_i, i = 0, 2, 4, \dots \text{ for first series}$$

$$\frac{a^{2i+1}}{(2i+1)!} 2^{n+1} \left[\frac{n+1}{2} \right]^2 Q_i = 26k_i + l_i, i = 1, 3, 5, \dots \text{ for second series}$$

Else use concept of congruence

Step 3: Consider $P_{i,j}$ for k_i and $27 - P_{i,j}$ for k_i which satisfies the values with the key values. Sender sends, if required use the concept of congruence.

Illustration

Given plain text "HOLA AMIGO" is equivalent to 8,15,12,1,0,1,13,9,7,15

The series explore to solve the problem is

$$\alpha^n \sin a\alpha = \alpha^n \left[a\alpha - \frac{(a\alpha)^3}{3!} + \frac{(a\alpha)^5}{5!} - \frac{(a\alpha)^7}{7!} + \dots \right] \\ = \sum_{i=0}^{\infty} \frac{(-1)^i (a\alpha)^{2i+1} (a\alpha)^{2i+n+1}}{(2i+1)!}$$

Where $a, n \in \mathbb{N}$ are constants

Take $a = 2, n = 2$

$$\text{So, } \alpha^2 \sin 2\alpha = \left[2\alpha^3 - \frac{2^3 \alpha^5}{3!} + \frac{2^5 \alpha^7}{5!} - \frac{2^7 \alpha^9}{7!} + \dots \right] \\ = \sum_{i=0}^{\infty} \frac{(-1)^i (2)^{2i+1} (a\alpha)^{2i+3}}{(2i+1)!}$$

Neglect higher order terms as per requirement.

Recognizing coefficients as

$$P_0 = 8, P_1 = 15, P_2 = 12, P_3 = 1, P_4 = 0, P_5 = 1, P_6 = 13, P_7 = 9, P_8 = 7, P_9 = 15$$

Write these numbers as coefficient of the series $\alpha^2 \sin 2\alpha$

Assuming $\varphi(t) = P_i \alpha^2 \sin 2\alpha$

We get

$$\varphi(t) = P_0 2\alpha^3 - P_1 \frac{2^3 \alpha^5}{3!} + P_2 \frac{2^5 \alpha^7}{5!} - P_3 \frac{2^7 \alpha^9}{7!} + P_4 \frac{2^9 \alpha^{11}}{9!} - P_5 \frac{2^{11} \alpha^{13}}{11!} + P_6 \frac{2^{13} \alpha^{15}}{13!} - P_7 \frac{2^{15} \alpha^{17}}{15!} + P_8 \frac{2^{17} \alpha^{19}}{17!} - P_9 \frac{2^{19} \alpha^{21}}{19!}$$

Solve alternating negative terms of the series using congruence property that $x \equiv y \pmod{27}$

$$\varphi(t) = 8[2\alpha^3] + 12 \left[\frac{2^3 \alpha^5}{3!} \right] + 12 \left[\frac{2^5 \alpha^7}{5!} \right] + 26 \left[\frac{2^7 \alpha^9}{7!} \right] + 0 \left[\frac{2^9 \alpha^{11}}{9!} \right] + 26 \left[\frac{2^{11} \alpha^{13}}{11!} \right] + 13 \left[\frac{2^{13} \alpha^{15}}{13!} \right] + 18 \left[\frac{2^{15} \alpha^{17}}{15!} \right] + 7 \left[\frac{2^{17} \alpha^{19}}{17!} \right] + 12 \left[\frac{2^{19} \alpha^{21}}{19!} \right]$$

Taking Hankel Transformation on both side





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We get,

$$H[\varphi(t)] = \frac{8(18)}{\rho^5} + \frac{12(300)}{\rho^7} + \frac{12(2940)}{\rho^9} + \frac{26(22680)}{\rho^{11}} + \frac{0(152460)}{\rho^{13}} + \frac{26(936936)}{\rho^{15}} + \frac{13(5405400)}{\rho^{17}} + \frac{18(29755440)}{\rho^{19}}$$

$$+ \frac{7(157966380)}{\rho^{21}} + \frac{12(814773960)}{\rho^{23}}$$

$$= \frac{144}{\rho^5} + \frac{3600}{\rho^7} + \frac{35280}{\rho^9} + \frac{589680}{\rho^{11}} + \frac{0}{\rho^{13}} + \frac{24360336}{\rho^{15}} + \frac{70270200}{\rho^{17}} + \frac{535597920}{\rho^{19}} + \frac{1105764660}{\rho^{21}} + \frac{9777287520}{\rho^{23}}$$

$$144 \equiv 9 \pmod{27}, 3600 \equiv 9 \pmod{27}, 35280 \equiv 18 \pmod{27}, 589680 \equiv 0 \pmod{27}, 0 \equiv 0 \pmod{27}, 24360336 \equiv 18 \pmod{27},$$

$$70270200 \equiv 0 \pmod{27}, 535597920 \equiv 0 \pmod{27}, 1105764660 \equiv 18 \pmod{27}, 9777287520 \equiv 0 \pmod{27}$$

9	9	18	0	0	18	0	0	18	0
I	I	R	—	—	R	—	—	R	—

Senders sends the values (Quotients in modulo operation)

$$H[\varphi(t)] = P_0 2 \left(\frac{9}{\rho^5} \right) + Q_1 \frac{2^3}{3!} \left(\frac{225}{\rho^7} \right) + P_2 \frac{2^5}{5!} \left(\frac{11025}{\rho^9} \right) + Q_3 \frac{2^7}{7!} \left(\frac{893025}{\rho^{11}} \right) + P_4 \frac{2^9}{9!} \left(\frac{108056025}{\rho^{13}} \right) + Q_5 \frac{2^{11}}{11!} \left(\frac{18261468225}{\rho^{15}} \right)$$

$$+ P_6 \frac{2^{13}}{13!} \left(\frac{4108830350625}{\rho^{17}} \right) + Q_7 \frac{2^{15}}{15!} \left(\frac{1187451971330625}{\rho^{19}} \right) + P_8 \frac{2^{17}}{17!} \left(\frac{428670161650355520}{\rho^{21}} \right)$$

$$+ P_9 \frac{2^{19}}{19!} \left(\frac{189043541287806828544}{\rho^{23}} \right)$$

Since $P_i \leq 26$

$$P_0 18 = 27k_0 + 9 \Rightarrow P_0 = \frac{27k_0 + 9}{18} \Rightarrow \begin{cases} k_0 = 1, P_0 = 2 \\ k_0 = 3, P_0 = 5 \\ k_0 = 5, P_0 = 8 \\ k_0 = 7, P_0 = 11 \\ k_0 = 9, P_0 = 14 \\ k_0 = 11, P_0 = 17 \\ k_0 = 13, P_0 = 20 \\ k_0 = 15, P_0 = 23 \\ k_0 = 17, P_0 = 26 \end{cases}$$

$$Q_1 300 = 27k_1 + 9 \Rightarrow Q_1 = \frac{27k_1 + 9}{300} \Rightarrow \begin{cases} k_1 = 33, Q_1 = 3 \\ k_1 = 133, Q_1 = 12 \\ k_1 = 233, Q_1 = 21 \end{cases}$$

$$P_2 2940 = 27k_2 + 18 \Rightarrow P_2 = \frac{27k_2 + 18}{2940} \Rightarrow \begin{cases} k_2 = 326, P_2 = 3 \\ k_2 = 1306, P_2 = 12 \\ k_2 = 2286, P_2 = 21 \end{cases}$$





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$$Q_3 22680 = 27k_3 + 0 \Rightarrow Q_3 = \frac{27k_3 + 0}{300} \Rightarrow \left\{ \begin{array}{l} k_3 = 0, Q_3 = 0 \\ k_3 = 840, Q_3 = 1 \\ k_3 = 1680, Q_3 = 2 \\ k_3 = 2520, Q_3 = 3 \\ k_3 = 3360, Q_3 = 4 \\ k_3 = 4200, Q_3 = 5 \\ k_3 = 5040, Q_3 = 6 \\ k_3 = 5880, Q_3 = 7 \\ k_3 = 6720, Q_3 = 8 \\ k_3 = 7560, Q_3 = 9 \\ k_3 = 8400, Q_3 = 10 \\ k_3 = 9240, Q_3 = 11 \\ k_3 = 10080, Q_3 = 12 \\ k_3 = 10920, Q_3 = 13 \\ k_3 = 11760, Q_3 = 14 \\ k_3 = 12600, Q_3 = 15 \\ k_3 = 13440, Q_3 = 16 \\ k_3 = 14280, Q_3 = 17 \\ k_3 = 15120, Q_3 = 18 \\ k_3 = 15960, Q_3 = 19 \\ k_3 = 16800, Q_3 = 20 \\ k_3 = 17640, Q_3 = 21 \\ k_3 = 18480, Q_3 = 22 \\ k_3 = 19320, Q_3 = 23 \\ k_3 = 20160, Q_3 = 24 \\ k_3 = 21000, Q_3 = 25 \\ k_3 = 21840, Q_3 = 26 \end{array} \right.$$

$$P_4 152460 = 27k_4 + 0 \Rightarrow P_4 = \frac{27k_4 + 0}{152460} \Rightarrow \left\{ \begin{array}{l} k_4 = 0, P_4 = 0 \\ k_4 = 16940, P_4 = 3 \\ k_4 = 33880, P_4 = 6 \\ k_4 = 50820, P_4 = 9 \\ k_4 = 67760, P_4 = 12 \\ k_4 = 84700, P_4 = 15 \\ k_4 = 101640, P_4 = 18 \\ k_4 = 118580, P_4 = 21 \\ k_4 = 135520, P_4 = 24 \end{array} \right.$$

$$Q_5 93696 = 27k_5 + 18 \Rightarrow Q_5 = \frac{27k_5 + 18}{93696} \Rightarrow \left\{ \begin{array}{l} k_5 = 69402, Q_5 = 2 \\ k_5 = 173506, Q_5 = 5 \\ k_5 = 277610, Q_5 = 8 \\ k_5 = 381714, Q_5 = 11 \\ k_5 = 485818, Q_5 = 14 \\ k_5 = 589922, Q_5 = 17 \\ k_5 = 694026, Q_5 = 20 \\ k_5 = 798130, Q_5 = 23 \\ k_5 = 902234, Q_5 = 26 \end{array} \right.$$





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$$P_6 5405400 = 27k_6 + 0 \Rightarrow P_6 = \frac{27k_6 + 0}{5405400} \Rightarrow \left\{ \begin{array}{l} k_6 = 0, P_6 = 0 \\ k_6 = 200200, P_6 = 1 \\ k_6 = 400400, P_6 = 2 \\ k_6 = 600600, P_6 = 3 \\ k_6 = 800800, P_6 = 4 \\ k_6 = 1001000, P_6 = 5 \\ k_6 = 1201200, P_6 = 6 \\ k_6 = 1401400, P_6 = 7 \\ k_6 = 1601600, P_6 = 8 \\ k_6 = 1801800, P_6 = 9 \\ k_6 = 2002000, P_6 = 10 \\ k_6 = 2202200, P_6 = 11 \\ k_6 = 2402400, P_6 = 12 \\ k_6 = 2602600, P_6 = 13 \\ k_6 = 2802800, P_6 = 14 \\ k_6 = 3003000, P_6 = 15 \\ k_6 = 3203200, P_6 = 16 \\ k_6 = 3403400, P_6 = 17 \\ k_6 = 3603600, P_6 = 18 \\ k_6 = 3803800, P_6 = 19 \\ k_6 = 4004000, P_6 = 20 \\ k_6 = 4204200, P_6 = 21 \\ k_6 = 4404400, P_6 = 22 \\ k_6 = 4604600, P_6 = 23 \\ k_6 = 4804800, P_6 = 24 \\ k_6 = 5005000, P_6 = 25 \\ k_6 = 5205200, P_6 = 26 \end{array} \right.$$

$$Q_7 29755440 = 27k_7 + 0 \Rightarrow Q_7 = \frac{27k_7 + 0}{29755440} \Rightarrow \left\{ \begin{array}{l} k_7 = 0, Q_7 = 0 \\ k_7 = 3306160, Q_7 = 3 \\ k_7 = 6612320, Q_7 = 6 \\ k_7 = 9918480, Q_7 = 9 \\ k_7 = 13224640, Q_7 = 12 \\ k_7 = 16530800, Q_7 = 15 \\ k_7 = 19836960, Q_7 = 18 \\ k_7 = 23143120, Q_7 = 21 \\ k_7 = 26449280, Q_7 = 24 \end{array} \right.$$

$$P_8 157966380 = 27k_8 + 18 \Rightarrow P_8 = \frac{27k_8 + 18}{157966380} \Rightarrow \left\{ \begin{array}{l} k_8 = 5850606, P_8 = 1 \\ k_8 = 23402426, P_8 = 4 \\ k_8 = 40954246, P_8 = 7 \end{array} \right.$$

$$Q_9 814773960 = 27k_9 + 0 \Rightarrow Q_9 = \frac{27k_9 + 0}{814773960} \Rightarrow \left\{ \begin{array}{l} k_9 = 0, Q_9 = 0 \\ k_9 = 90530440, Q_9 = 3 \\ k_9 = 181060880, Q_9 = 6 \\ k_9 = 271591320, Q_9 = 9 \\ k_9 = 362121760, Q_9 = 12 \\ k_9 = 452652200, Q_9 = 15 \\ k_9 = 543182640, Q_9 = 18 \\ k_9 = 633713080, Q_9 = 21 \\ k_9 = 724243520, Q_9 = 24 \end{array} \right.$$

So, the given cipher text is equivalent to

8	15	12	1	0	1	13	9	7	15
H	O	L	A	—	A	M	I	G	O





CONCLUSION

By using trigonometric ratio and applying a mathematical technique called the Hankel Transform. We can establish a secure method for transmitting data. This approach can also be extended to explore other types of ratios for mathematical series for opening a new avenue for research in this field.

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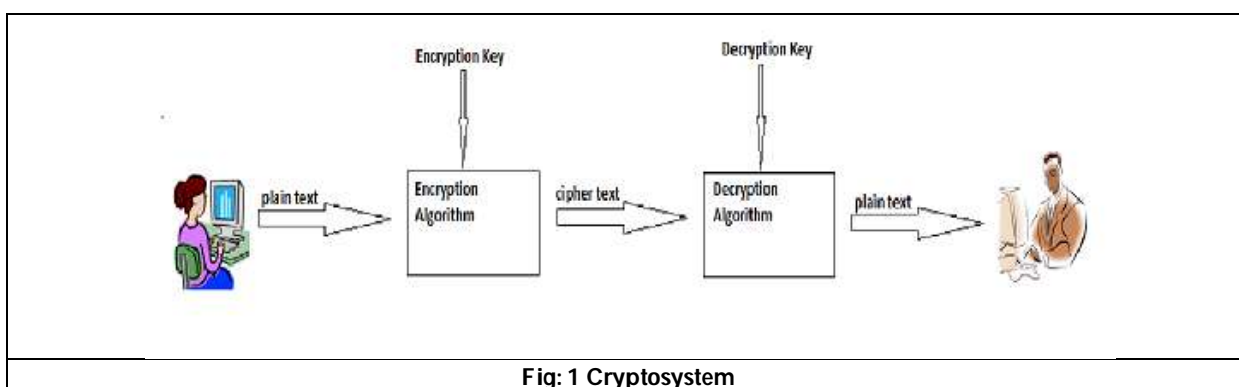


Fig: 1 Cryptosystem





Hyaluronic Acid in Dentistry : A View Point

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ABSTRACT

Hyaluronic acid (HA) is a glycosaminoglycan found abundantly in the human body, particularly in body fluids and the extracellular matrix of tissues. It plays a vital role in maintaining tissue hydration and supporting cellular processes such as proliferation, differentiation, and the inflammatory response. Due to its biocompatibility, biodegradability, non-toxicity, and non-immunogenic properties, numerous HA-based biomedical products have been developed. There is growing interest in optimizing HA production processes to ensure high-quality, efficient, and cost-effective products. Topical applications of HA have long been recognized as effective for delivering treatments to both soft tissues, such as the periodontal ligament, and hard structures like the alveolar bone and cementum. Recently, HA's use has gained prominence as an adjunctive treatment for chronic inflammation, in addition to its well-established role in promoting healing following dental procedures. This review article aims to provide valuable insights into the future potential of HA in dentistry, encouraging clinicians and the next generation of dentists to incorporate its use into their practice.

Keywords: Hyaluronic acid, Dentistry, Glycosaminoglycans, Inflammation, Wound Healing, Topical Applications.





INTRODUCTION

Hyaluronic acid (HA) is a naturally occurring, non-sulfated glycosaminoglycan with a high molecular weight ranging from 4,000 to 20,000,000 Da. Its structure is composed of repeating disaccharide units of glucuronic acid and N-acetylglucosamine, linked by alternating β -1,3 and β -1,4 glycosidic bonds. HA is a linear polysaccharide found in the extracellular matrix of connective tissues, synovial fluid, embryonic mesenchyme, vitreous humor, skin, and various other organs and tissues throughout the body.[1] Hyaluronic acid, also referred to as hyaluronan was first isolated by Mery and Palmer in 1934.[2] Cross-linked hyaluronic acid (xHyA) is produced by a process that establishes new bonds between linear or native HA, effectively linking the molecules through cross-linking. Hyaluronic acid (HA) is among the most moisture-absorbing molecules found in nature. When HA is mixed with an aqueous solution, hydrogen bonding takes place between the carboxyl and N-acetyl groups, enabling HA to maintain its structural rigidity and retain moisture. Additionally, HA exhibits significant viscoelastic properties, which help reduce the penetration of viruses and bacteria into tissues.[3] The molecule plays a crucial role in the various stages of the wound-healing process. These stages include inflammation, granulation tissue formation, epithelial formation, and tissue remodelling. Due to the numerous functions associated with hyaluronic acid, significant progress has been made in the development and use of HA-based biomaterials for treating various inflammatory conditions.[4] Given the multifunctional roles of hyaluronic acid in wound healing, and considering that gingival and bone healing follow similar biological processes, it is reasonable to believe that HA plays similar roles in the healing of both mineralized and non-mineralized tissues within the periodontium.[3] A Systematic review in 2015,[5] showed the potential benefits of topical hyaluronic acid (HA) in treating both acute and chronic inflammatory diseases of the upper aerodigestive tract. In recent years, HA formulations have been developed for topical use as an adjunct treatment for acute and chronic dental and gingival conditions, such as promoting tissue healing after oral surgery.[6] This review article aims to explore and discuss the various physicochemical, biochemical, and pharmacotherapeutic applications of hyaluronic acid, with a focus on its use in different areas of dentistry.

REVIEW

SEARCH METHODOLOGY

Relevant published studies were searched for on PubMed, Google Scholar using keywords such as “hyaluronic acid in dentistry”, “hyaluronic acid AND oral surgery”, “hyaluronic acid AND periodontology”, “hyaluronic acid AND orthodontics”, “hyaluronic acid AND pedodontics”, “hyaluronic acid AND aesthetic dentistry”. Key references were also gathered from the bibliographies of the relevant studies.

Properties of HA

Hyaluronic acid serves multiple functions in the body, utilizing its physicochemical and biological properties. The biological functions of hyaluronic acid range from fundamental structural roles in the extracellular matrix to regulating development by influencing cell behaviour through the control of both tissue macro- and microenvironments. Additionally, these functions of HA have direct receptor-mediated effects on gene expression. Hyaluronic acid displays hygroscopic and viscoelastic properties. It also demonstrates bacteriostatic activity, which is most pronounced when higher concentrations of the medium and lower molecular weight HA are used.[8] Additionally, HA is biocompatible and non-immunogenic. Hyaluronic acid demonstrates anti-inflammatory properties by scavenging prostaglandins, metalloproteinases, and other bioactive molecules.[9] It also possesses antioedematous properties due to its osmotic action and antioxidant capabilities. By scavenging reactive oxygen species, HA helps stabilize the granulation tissue matrix.[10]

Synthesis of HA

Hyaluronic acid is a negatively charged glycosaminoglycan that distinguishes itself from other glycosaminoglycans. In mammals, HA synthesis takes place at the cellular plasma membrane, whereas the synthesis of other



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glycosaminoglycans typically occurs in the Golgi apparatus. Hyaluronic acid synthesis is carried out by three isoenzymes of hyaluronan synthase (HAS1, HAS2, and HAS3).¹¹ The highest concentrations of hyaluronic acid are found in the synovial fluid, epidermis, umbilical cord, and other tissues, whereas the lowest concentration is present in the blood serum. A membrane-bound protein in plasma membranes synthesizes hyaluronic acid by transporting activated monosaccharides to glycosaminoglycan chains and releasing uridine diphosphate directly into the extracellular space. Hyaluronic acid turnover in tissues is influenced by lymphatic drainage into the circulatory system or local metabolism.¹²

Characteristic features of HA

Hyaluronic acid is not a single molecule, but a family of molecules with varying characteristics. These differences are significant and can result in diverse effects. Below are some key features:

• Low molecular weight vs. high molecular weight

The physiological functions of hyaluronic acid are influenced by its molecular weight (MW), which is determined by the length of its chain. High molecular weight (long chain) hyaluronic acid primarily plays a role in modulating the immune response through its immunosuppressive, antiangiogenic, and anti-inflammatory effects.¹³ In contrast, low molecular weight (short chain) hyaluronic acid is important for wound and tissue healing, as it exhibits angiogenic, immunostimulatory, and pro-inflammatory properties.¹³

• Purity

The purity of hyaluronic acid can vary considerably based on its intended application. There are significant differences in the quality of HA used for cosmetic versus surgical or pharmaceutical purposes. Generally, HA produced for surgical or pharmaceutical use meets the highest standards and ensures superior quality.

• Native/linear versus cross-linked hyaluronic acid (xHyA)

The choice between native and cross-linked hyaluronic acid depends on the specific application and desired effect. Native HA maintains its natural structure and offers the greatest regenerative potential, being naturally degraded in the body within a few hours to a few days. Cross-linked hyaluronic acid (xHyA) undergoes chemical modifications to extend its degradation time, which can range from several weeks to months. However, as HA becomes cross-linked, its physiological properties are diminished, and it becomes more inert. When selecting the appropriate type of HA for medical devices, it is crucial to consider the specific requirements and intended use.⁸

• Composition of hyaluronic acid-based gels

HA-based gels designed for specific applications can differ in several aspects:

Concentration

The concentration of hyaluronic acid in the gel can affect its viscosity and potentially its effectiveness. Higher concentrations typically lead to increased viscosity, which may improve the device's performance.

Composition

HA formulations can be composed of a single type of hyaluronic acid aimed at targeting a specific tissue or healing process. Alternatively, some formulations may contain multiple types of HA, each designed to address different healing patterns or tissue types.⁹

Additional substances

HA formulations may contain additional ingredients such as disinfectants, peptides, polynucleotides, mannitol, or viscosity modifiers. These substances can potentially interact with the beneficial properties of HA, influencing its resorption pattern and regenerative effects. Essential considerations to follow¹⁴:



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- The formulation must align with the biological requirements of the indication (e.g., bone augmentation requires a prolonged effect, while gingival wound healing typically occurs over a few days).
- It should also match the specificity of the application (e.g., gel for direct application to the surgical site, HA combined with other biomaterials, or non-surgical use for periodontal pockets).
- Additionally, potential interactions must be considered to achieve the desired outcomes (e.g., high molecular weight cross-linked hyaluronic acid slows the resorption of collagen, such as collagen membranes).

Application of HA in dentistry

Hyaluronic acid promotes healing and reduces inflammation. It can be applied topically to oral mucosa, gums, or soft tissues, injected to treat gingival recession or enhance a smile, or used around dental implants to improve osseointegration. HA can also be applied as a gel or film for tissue regeneration, or added to mouthwash to reduce periodontal infections and support healing.¹⁵

HA in Oral and Maxillofacial Surgery

Hyaluronic acid can be injected into soft tissue to enhance volume and appearance. It aids in wound healing by enhancing tissue regeneration, decreasing inflammation, and stimulating angiogenesis. HA aids recovery after oral procedures, such as tooth extractions or implants, and enhances bone density and osteogenesis in bone regeneration, particularly in the maxillofacial area. It also improves outcomes in bone grafting surgeries.¹⁶ Hyaluronic acid injections into the joint space can treat temporomandibular disorders by reducing inflammation, improving lubrication, and promoting tissue regeneration. Extensive research supports the use of hyaluronidase in TMJ issues.¹⁷ Hyaluronidase is an enzyme that breaks down hyaluronic acid in joint spaces and synovial fluid, increasing the viscosity of the synovial fluid. It works by enhancing fluid absorption and synovial permeability, allowing for the dispersion of traumatic exudates and transudates.¹⁸ Hyaluronic acid proves to be highly effective following third molar surgery. Yilmaz *et al.*¹⁹ evaluated the benefits of HA after the surgical extraction of third molars. The study suggested that hyaluronic acid could provide an analgesic effect in post-extraction sockets, reducing the need for nonsteroidal anti-inflammatory drugs after dentoalveolar surgery. A study by Koray *et al.*²⁰ also showed that HA spray was more effective than benzydamine hydrochloride spray.

HA in Periodontal Therapy

Hyaluronic acid plays a significant role in periodontal treatment, offering anti-inflammatory, antibacterial, anti-edematous, and tissue regeneration properties. Studies show it can reduce pocket depth, improve attachment levels, and decrease bleeding on probing, while its antibacterial effects help treat periodontal diseases.²¹ It can be injected into gum tissue to promote regeneration, reduce inflammation, and restore the natural gum position. It is also used in pocket reduction therapy to treat periodontal pockets, where bacteria can cause inflammation.¹⁶ Hyaluronic acid can be applied in periodontal surgery to enhance healing and tissue regeneration. It can be used topically or injected into the surgical site to reduce inflammation and support wound healing. HA is often combined with scaling and root planning and can be applied or injected into the gum tissue to promote regeneration and minimize inflammation. It has a strong ability to bind water, keeping the tissue moist and support healing. Additionally, it stimulates the proliferation of fibroblasts and other connective tissue cells, aiding in tissue regeneration.²² Gontiya *et al.* showed that subgingival application of 0.2% HA gel with scaling and root planing (SRP) in chronic periodontitis patients resulted in improved gingival and bleeding indices compared to control sites. This was further confirmed by a gingival biopsy, which revealed a significant reduction in inflammatory infiltrate.²³ Erik *et al.* showed the effect of HA topically used with varying concentrations. The HA group in his study showed positive results with reduction in periodontal pocket depth and prevention of further recolonization of pathogens such as *Campylobacter*, *P. intermedia*, and *P. gingivalis*.²⁴ Hyaluronic acid is also used in periodontics as a filler for periodontal issues. It can be injected into areas of gum recession or other abnormalities to fill gaps and stimulate tissue regeneration. Due to its anti-inflammatory and regenerative properties, HA is a promising biomaterial in periodontics, with the potential to improve treatment outcomes and reduce the need for more invasive gum disease procedures.²⁵



**HA in Pedodontics**

Hyaluronic acid is used to treat oral ulcers, a common condition in children that causes discomfort and pain. It can be applied topically or used as a mouthwash to reduce inflammation and promote healing. Nolan *et al.* proved that 0.2% HA gel when applied twice daily for two weeks was effective in treating recurrent aphthous ulcers. 260.2% HA gel was also used in the treatment of gingivitis in children. HA as topical gel or mouthwash could also be used to decrease the inflammation and accelerate tissue repair after orthodontic treatment in younger patients. Hyaluronic acid can be applied topically or injected into the soft tissues around orthodontic devices to relieve discomfort and improve outcomes. In caries prevention, HA has been studied for its potential to combat dental caries, a common issue in children. It can be applied topically to the teeth to reduce bacterial growth and support remineralization.²⁷

HA in Implant Dentistry

Hyaluronic acid has been shown to enhance osseointegration and decrease implant failure rates. Studies indicate that HA use can increase bone density around dental implants, improving their stability and longevity, ultimately contributing to a longer lifespan for the implant. Cervino *et al* demonstrated in his study that HA promotes the migration, adhesion, proliferation, and differentiation of cell precursors on titanium implants. By increasing the bioactivity of implant surfaces, HA helps ensure accurate positioning of dental prostheses during the early loading period, meeting patient expectations. Hyaluronic acid, a key glycosaminoglycan in the cellular matrix produced by fibroblasts, synovocytes, and chondrocytes, helps reduce inflammation during wound healing. It promotes cell proliferation, re-epithelialization, and scar reduction.²⁸

HA in Endodontics

Research shows that hyaluronic acid reduces postoperative discomfort and promotes recovery after endodontic procedures due to its anti-inflammatory effects.²⁹ It is used as an intracanal medicament to aid healing and regeneration of periapical tissues post-root canal therapy. HA also serves as an effective root canal irrigant, removing debris and smear layers. Additionally, it is used as a filling material for root perforations and resorptive defects, possible due to its biocompatibility and regenerative properties.²⁸

HA in Orthodontics

Hyaluronic acid reduces pain and discomfort during orthodontic therapy while promoting faster tooth movement by enhancing osteoclast and osteoblast activity. Its anti-inflammatory and antibacterial properties help reduce inflammation and improve healing in periodontal tissues. HA can also be used as a lubricant to reduce friction between brackets and archwires, increasing patient comfort. Additionally, it helps prevent white spot lesions and may offer a cost-effective solution for both patients and the healthcare system.³⁰

HA in Facial Aesthetics

A growing field within maxillofacial surgery is aesthetic surgery, which includes various non-surgical techniques for facial rejuvenation or augmentation to enhance facial appearance. These treatments treat signs of aging like wrinkles, fine lines, volume loss, and sagging skin. Hyaluronic acid is commonly used as a dermal filler in facial aesthetics, gaining popularity for its ability to enhance facial contours, restore volume, and improve skin appearance.³¹ When injected, HA adds volume and plumps the skin, helping to fill wrinkles, folds, and lines. Injecting hyaluronic acid into the lips can enhance their shape and fullness, and it is also used in other cosmetic procedures, such as lip augmentation.³² HA fillers can define and contour the jawline for a more sculpted appearance. As an organic compound, HA is well-tolerated by the body, with temporary and reversible effects. The effects of HA dermal fillers usually persist for several months to up to a year, depending on the composition and the metabolic rate.³³

CONCLUSION

Hyaluronic acid is a versatile biomaterial with multiple applications in dentistry. Its role in periodontal treatment, implant dentistry, endodontics, facial aesthetics, oral surgery, and orthodontics has been extensively studied. Due to



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its biocompatibility, regenerative properties, and antibacterial benefits, HA is a highly attractive material for various dental treatments. HA's versatility in modern dentistry offers significant potential for innovative dental products and treatments. Future research should focus on optimizing HA formulations, exploring new delivery methods, and discovering additional applications. Combining HA with other biomaterials, drugs, and growth factors could enhance its regenerative potential.

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A Comparative Analysis of Employee Psychological Contract in Manufacturing vs IT and ITES Companies

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ABSTRACT

The study examines the difference in psychological contract (PC) between the employees working in IT and manufacturing sectors. Several researchers have studied the concepts of psychological contract in various sectors. Through an exhaustive literature survey, it can be understood that when objectively measured, employee psychological contract varies from sector to sector. This paper contemplates two such dynamic industries i.e., manufacturing and IT/ITES, and aims at comparing the psychological contract of employees working in these sectors. This research is inspired by an article on attrition rate in Q3, published in January 2023, by the Economic Times. 176 employees working in IT and manufacturing sectors were selected as respondents using probability sampling technique. A pilot tested questionnaire and interviews were used to collect the responses. To test the hypothesis developed during the research, Analysis of Variance (ANOVA) was used. The analysis was performed using SPSS software. Besides comparison of psychological contract, the paper also attempts to identify and examine the variables that influence consistent maintenance of psychological contract in these sectors. In a nutshell, the analysis revealed similar perspectives of employees for factors such as involvement and external marketability while it differed for other factors namely stability of tenure, loyalty, performance support and growth and development plans. However, the strength of PC among the employees in the manufacturing





industry appeared to be stronger in comparison with IT/ITES sectors. Future research can focus on longitudinal studies to analyse the changes in PC more accurately over a period of time.

Keywords: Attrition rate, Employee engagement, Psychological contract, IT/ITES, Manufacturing.

INTRODUCTION AND PURPOSE

Employees are the most important assets of any organization. Today's dynamic environment has made every organization strive to attract and retain best talents irrespective of the industry. The organization has to engage these employees enhancing their skills to adapt to ever changing markets. In this process of attraction to retention the organizations make a huge investment on its people, despite of which, many organizations are witnessing high attrition rate tossing out all the effort, time and money. According to an article on attrition rate in Q3, published by Economic times in January 2023 IT/ITES sector suffered from highest attrition rate of close to 27.19% while in the manufacturing, engineering and infrastructure it was close to 8.27% in the world. These statistics stimulated this research to understand the underlying causes of attrition in the above mentioned massive labour-intensive sectors from the perspective of psychological contract (Argyris, 1960; Rousseau, 1989; Levinson *et al.*, 1962; Schein, 1965). This paper attempts to understand the PC of employees working in the IT industry where attrition rate is astoundingly high and manufacturing sector where the attrition is significantly low. The study also aims at understanding the factors influencing the sustenance of PC among employees in these sectors.

Theoretical background

Meaning of Psychological Contract (PC)

Psychological contract is understood to be an undocumented or unwritten agreement between an employee and the employer (Argyris, 1960; Levinson *et al.*, 1962; Schein, 1965). It plays a vital role in maintenance of smoother relationship between employee and employer (Kelly Windle & Kathryn von Treuer, 2014) PC is seen in various stages during the career of an employee, namely pre-employment stage, early socialization stage and latter stages. The development of PC is dependent on a person's social and organizational experiences (Rousseau *et al.*, 2013). Most of the researches classifies PC into two types, transactional and relational (Zhen Yan & ZurainaBt Dato Mansor, 2019). Some of the researches have also mentioned about other types such as transitional and balanced psychological contracts (Rousseau, 2000; Hui, Lee & Rousseau, 2004; Sims, 1994). Studies have also shown examples of dominant relational contract and employee PC being stronger than employer PC in industries such as Information Technology (Patrick, 2008).

Evolution of PC

The origins of the psychological contract can be traced back to the 1960s, with seminal contributions from Chris Argyris and Douglas McGregor. Argyris (1960) introduced the term "psychological work contract" to describe the informal agreement between employees and their supervisors, emphasizing the reciprocal nature of this exchange. McGregor (1960), through his Theory X and Theory Y, highlighted the significance of managerial assumptions about employee motivation and behaviour in shaping psychological contracts. In the early 1970s, Chris Argyris and Edgar Schein further developed the concept of the psychological contract. Argyris argued that the psychological contract is a dynamic agreement that is constantly being negotiated between employees and organizations. Schein proposed that the psychological contract is based on four key elements called expectations, obligations, perceived reality and outcomes (Schein, 1965). Having considered the social exchange theory as a foundation to PC (Coyle-Shapiro & Parzefall, 2008; Amanuel G. Tekleab *et al.*, 2019), several researchers defined it as a set of expectations and obligations between an employee and the employer (Argyris, 1960; Levinson *et al.*, 1962). Further, more clear understanding was provided by Denise Rousseau, who defined PC as "Perceived mutual obligations" (Rousseau, 1989). Rousseau also separated PC from official or legal contract in her further work on PC (Rousseau & Wade-Benzoni, 2006).





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The concept of PC leads to two thoughts, called Formation of PC and breach of PC (Robinson & Morrison, 1995; Coyle-Shapiro & Parzefall, 2008). Due to the fact that Psychological contract is literally psychological, some of the researches have argued about the complexity of measuring PC objectively. Eventually few researches highlighted the criteria any instrument is expected to satisfy in order to measure PC (Charissa Freese and Rene Schalk, 2015).

PC and performance

To describe the relationship between psychological contract and employee performance a causal loop diagram created using vensim software is shown in the Fig. 1.

The following interpretations can be drawn through this model.

Loop 1 (Reinforcing loop)

- Stronger PC motivates a person to perform more. This especially holds good during the early socialization stage. Increased performance results in rewards and recognition, which further strengthens the PC. The polarity (+ or -) indicates whether or not the variables are directly proportional.

Loop 2 (Balancing loop)

- With growing experience, gradually the performance decreases due to several reasons such as monotony, reduced motivation to work, lack of recognition, lack of support from supervisor etc. This weakens the PC. Nevertheless, the employee engagement activities such as promotion, appraisal, rewards etc. attempts to further strengthen it, with seldom possibilities of enhancing it to a greater extent. Eventually the PC tend to diminish resulting in separation of an employee. The delay mark in the loop indicate that the process is usually gradual.

Identification of factors and data collection

With a limited literature survey, we understand that there are various factors influencing PC in different stages. During pre-employment stage it depends on a person's awareness about the role and the organization, formal education and his preparedness to work (Schein, 1965). During the early socialization stage and latter stages, period of employee-employer relationship, employee engagement initiatives, salary and benefits, supervisor support, employment status, market conditions etc. (Heather Maguire, 2003) plays a vital role. There are also instances where working conditions have changed with economy, political conditions, advancements in technology, globalization etc. and in turn these affect PC (Patrick, 2008). Psychological contract inventory (Rousseau, 2008) a systematic instrument was adapted to design the survey instrument required for this study. Fig. 2 shows the factors considered for the study. These factors are similar to those used by Rousseau (2008) divided into four types of psychological contracts (Transactional, relational, balanced and transitional). The objective was to compare the psychological contract of employees working in IT sectors vs those in manufacturing sector. As mentioned earlier, few studies have measured the PC of employees in IT sector and have found the dominance of relational contract. In this study, the PC of IT employees was compared with that of manufacturing employees. The reliability measure of the instrument is shown in the Fig. 3. Under each factor, the first question consisted of dichotomous choices to check if PC is formed. The second question consisted of 5-point Likert choices to check the strength of PC formed. Example, if a person's answer is a "Yes" for a question under a particular factor, it may not imply a positive PC unless the response for the second question has a similar inference. The questionnaire had two segments. Segment 1 consisted of questions from employees' perspective (What employee thinks he owes to the company/employer). Segment 2 consisted of questions regarding employees' view about employer (What employee thinks employer owes him). Both segments were answered by the employees and considered same factors. The first hypothesis developed aimed at understanding stability of tenure of the employees from both IT and manufacturing sectors. In other words, the respondents' intention to leave the company. Similarly, for every factor the hypothesis developed is shown in the table below:

RESEARCH METHODS AND TECHNIQUES

As the study intended to describe the portrayal of behaviour of employees, a descriptive research was used. The respondents were selected based on stratified sampling technique. The questionnaire was circulated using online



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survey platforms to approximately 200 respondents, of which 176 responded. Of these respondents, 84 worked in IT/ITES industry and the rest worked in manufacturing industry. The respondent profile in brief is as specified below:

ANALYSIS AND DISCUSSION OF RESULTS

As discussed earlier, PC differs employee to employee and from sector to sector depending on the stage of employment, market conditions, salary and benefits and many other variables.

However, as analysing the PC between employees in the same sector would be quite time consuming, the study aimed at analysing the PC between employees and employers of both manufacturing and IT/ITES sectors, keeping intra-sector PC as a control variable. To analyse these differences, analysis of variance (ANOVA) was used on SPSS software at the significant level (α) of 0.05.

It is important to note that for every measure of ANOVA, the independent variable is the sector and dependent variable is the factor considered. Also, for every measure there are two interpretations possible.

1. Comparison of PC (EE) between employees from both the sectors represented as Q_i (PCI Vs PCM, EE), where the value of "i" ranges from 1 to 6
2. Comparison of PC (ER) between employees from both the sectors represented as Q_j (PCI Vs PCM, ER), where the value of "j" ranges from 7 to 12

Hypothesis 1

The p -value shown at the end of the above table is less than 0.05 at 5 percent level of significance for both measurements (Q_1 and Q_7). Hence, we reject the null hypothesis for both Q_1 and Q_7 .

The following interpretations are drawn based on these values.

- Q_1 (PCI Vs PCM, EE) – The difference in the psychological contracts between employees from both sectors is significantly higher. The F value indicates higher variation among these two groups with reference to what employees owe to the employer.
- Q_7 (PCI Vs PCM, ER) – The variance between the employees from both sectors is lesser compared with that of Q_1 . This means the level of agreement or in other words, similarity of thoughts between both sectors is higher with reference to what the employer owes to them.
- From the perspective of tenure, the PC between employees and employers of both sectors combined appears to be different. Where there are differences, the possibility of unstable PC is higher. It means majority of the employees feel that they are not obligated to stay in the company for longer tenure, and they also feel that their employers might not offer a stable employment. However, the primary data collected and interviews conducted with employees and employers suggest that the "Fear of job un-stability" is higher in IT/ITES than manufacturing sector.

Hypothesis 2

In the above case, Q_2 and Q_8 shows the 'loyalty' factor. The p -value of Q_2 is less than 0.05, and hence we reject the null hypothesis for Q_2 . But for Q_8 the p -value is more than 0.05 at 5 percent level of significance. Hence, we fail to reject the null hypothesis.

The following interpretations are drawn based on these values.

- Q_2 (PCI Vs PCM, EE) – The F value indicate that the variation between the two sectors is high. Hence their interpretation of "loyalty" could be entirely different. Primary data and interview responses collected reveal that the relational contracts were dominant more among employees from manufacturing sectors than IT/ITES.
- Q_8 (PCI Vs PCM, ER) – Here we can observe the higher p -value and lesser F value indicating the variation among the employees is less. Both the sectors feel that their employers value their interests while making any decision.



**Hypothesis 3**

The following interpretations are drawn in the above case:

- Q3(PCI Vs PCM, EE) – The p -value in the above table for Q3 is more than 0.05, due to which we fail to reject the null hypothesis.
- Q9(PCI Vs PCM, ER) – The p -value in the above table for Q9 is also more than 0.05, due to which we fail to reject the null hypothesis.

The above values could mean that the employees have similar thoughts with reference to work involvement factor. So, there might not be notable difference in the level of PC among both sectors.

A careful observation of p -values ($Q3 > Q9$) from the context of work involvement, might indicate that the strength of PC between employees and employers considering both groups as one is relatively low. The employers seem to have an upper hand indicating lower involvement of employees. In other words, the PC of employees could be diminishing due to unfulfilled demands, amongst other unidentified reasons.

Hypothesis 4

The following interpretations are drawn in the above case:

- Q4(PCI Vs PCM, EE) – The p -value in the above table for Q4 is slightly higher than 0.05. However, this value is not strong enough to completely reject the null hypothesis.
- Q10(PCI Vs PCM, ER) – The p -value in the above table for Q10 is less than 0.05, due to which we can reject the null hypothesis.

These values indicate that with reference to performance support the variation between both the groups appear to be similar. Overall, we can understand that though the value of Q4 is slightly higher than Q10, it appears that the strength of PC is partial but need not be unstable. It means, the employers expect the employees to quickly adapt to changing situations and provide them performance support, but employees don't find it obligatory to a greater extent.

Hypothesis 5

The p -value in the above table is lesser than 0.05 for both measurements [Q5(PCI Vs PCM, EE and Q11(PCI Vs PCM, ER)] and hence in this case, we reject the null hypothesis. The F value shows higher variation in Q5 than Q11, which means that there is a significant difference between employees' perspectives, though there is a slight possibility that the expectations from employees are higher than fulfilment initiatives by the employers.

Hypothesis 6

In the above table, we fail to reject the null hypothesis as the p -value is higher than 0.05 for both the measurements [Q6(PCI Vs PCM, EE and Q12(PCI Vs PCM, ER)]. The values indicate an interesting result, that both employees and employers are on the same page, even between the employees, the variations are quite similar. But the strength of PC could be lower or unstable in other words. It means, neither the employees want to restrict themselves from being visible to external world, nor their employers expect them to be confined to their internal environment. So, either way, it might result in separation of an employee eventually.

DISCUSSION AND PRACTICAL IMPLICATIONS

The practical implications of the study can be two folded. Firstly, understanding the strength of psychological contract plays a vital role in shaping an employee's willingness to perform better and its fulfilment helps building a constructive relationship between an employee and the employer. But slightest difference in the working conditions may alter the PC. While positive changes in PC enhances the performance and engagement of an employee, negative changes might create damaging effects such as increased attrition, bad word of mouth communication, reduced performance etc. Second, the overall analysis results reveal that there is a significant difference in the perspectives of employees working in the selected sectors. As mentioned earlier, the relational psychological contract is more dominant in manufacturing sector than IT/ITES sector. With the dynamic changes in technology, the human





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relational touch seems to be missing. Dominant transactional PC might have a negative impact in the longer run. The present-day organizations must frame their employee engagement strategies so as to assure a positive effect on the PC, for which timely measurement of PC becomes inevitable.

Limitations and Future scope of the research

The study has two major limitations. First is the geographical limitation. The samples were limited to the Karnataka state in India. Being sixth largest state in the country by area, the state has diverse cultural and social practices and beliefs, which also affects the way every individual thinks. Therefore, the study may not be generalizable at this stage. Second, the study only compares PC between two sectors but does not quantify the psychological contract of each sector individually as it would take more time. Future research can focus on longitudinal studies to analyse the changes in PC more accurately over a period of time.

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Table 1: Hypothesis

Factor	Hypothesis
Stability of Tenure	H1 – There is a significant difference between PC of employees from both the sectors with respect to stability of tenure.
Loyalty	H2 - There is a significant difference between PC of employees from both the sectors with respect to loyalty
Involvement	H3 - There is a significant difference between PC of employees from both the sectors with respect to work involvement
Performance support	H4 - There is a significant difference between PC of employees from both the sectors with respect to performance support
Growth and development plans	H5 - There is a significant difference between PC of employees from both the sectors with respect to growth and development plans
External marketability	H6 - There is a significant difference between PC of employees from both the sectors with respect to external marketability

Table.2: Respondent Profile

	Options	No. of Respondents
Age Group	20 to 30	86
	30 to 40	59
	40 to 50	26
	Above 50	5
Gender	Male	58
	Female	118
Highest Qualification	Undergraduate	109
	Graduate	48
	Post graduate	19
Total Experience	Less than 5 years	25
	5 to 10 years	75
	10 to 15 years	42
	Above 15 years	34
Experience in the present Company	Less than 2 years	14
	2 to 4 years	77
	4 to 6 years	48
	6 to 8 years	11
	8 to 10 years	17
	Above 10 years	9

Table.3: Hypothesis 1

ANOVA Table ^a							
			Sum of Squares	df	Mean Square	F	Sig.
Q1 * Sector	Between Groups	(Combined)	90.979	1	90.979	57.034	.000
	Within Groups		277.561	174	1.595		
	Total		368.540	175			
Q7 * Sector	Between Groups	(Combined)	11.460	1	11.460	6.703	.010
	Within Groups		297.489	174	1.710		
	Total		308.949	175			

a. The grouping variable Sector is a string, so the test for linearity cannot be computed.

Source: SPSS





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Table.4: Hypothesis 2

ANOVA Table ^a							
			Sum of Squares	df	Mean Square	F	Sig.
Q2 * Sector	Between Groups	(Combined)	16.575	1	16.575	10.665	.001
	Within Groups		270.420	174	1.554		
	Total		286.994	175			
Q8 * Sector	Between Groups	(Combined)	.158	1	.158	.162	.688
	Within Groups		170.387	174	.979		
	Total		170.545	175			

a. The grouping variable Sector is a string, so the test for linearity cannot be computed.

Source: SPSS

Table.5: Hypothesis 3

ANOVA Table ^a							
			Sum of Squares	df	Mean Square	F	Sig.
Q3 * Sector	Between Groups	(Combined)	.301	1	.301	.382	.537
	Within Groups		137.244	174	.789		
	Total		137.545	175			
Q9 * Sector	Between Groups	(Combined)	2.216	1	2.216	1.331	.250
	Within Groups		289.580	174	1.664		
	Total		291.795	175			

a. The grouping variable Sector is a string, so the test for linearity cannot be computed.

Source: SPSS

Table.6: Hypothesis 4

ANOVA Table ^a							
			Sum of Squares	df	Mean Square	F	Sig.
Q4 * Sector	Between Groups	(Combined)	12.119	1	12.119	7.815	.006
	Within Groups		269.830	174	1.551		
	Total		281.949	175			
Q10 * Sector	Between Groups	(Combined)	15.208	1	15.208	9.855	.002
	Within Groups		268.514	174	1.543		
	Total		283.722	175			

a. The grouping variable Sector is a string, so the test for linearity cannot be computed.

Source: SPSS

Table.7: Hypothesis 5

ANOVA Table ^a							
			Sum of Squares	df	Mean Square	F	Sig.
Q5 * Sector	Between Groups	(Combined)	27.179	1	27.179	18.150	.000
	Within Groups		260.549	174	1.497		
	Total		287.727	175			
Q11 * Sector	Between Groups	(Combined)	5.584	1	5.584	4.892	.028
	Within Groups		198.637	174	1.142		
	Total		204.222	175			

a. The grouping variable Sector is a string, so the test for linearity cannot be computed.

Source: SPSS



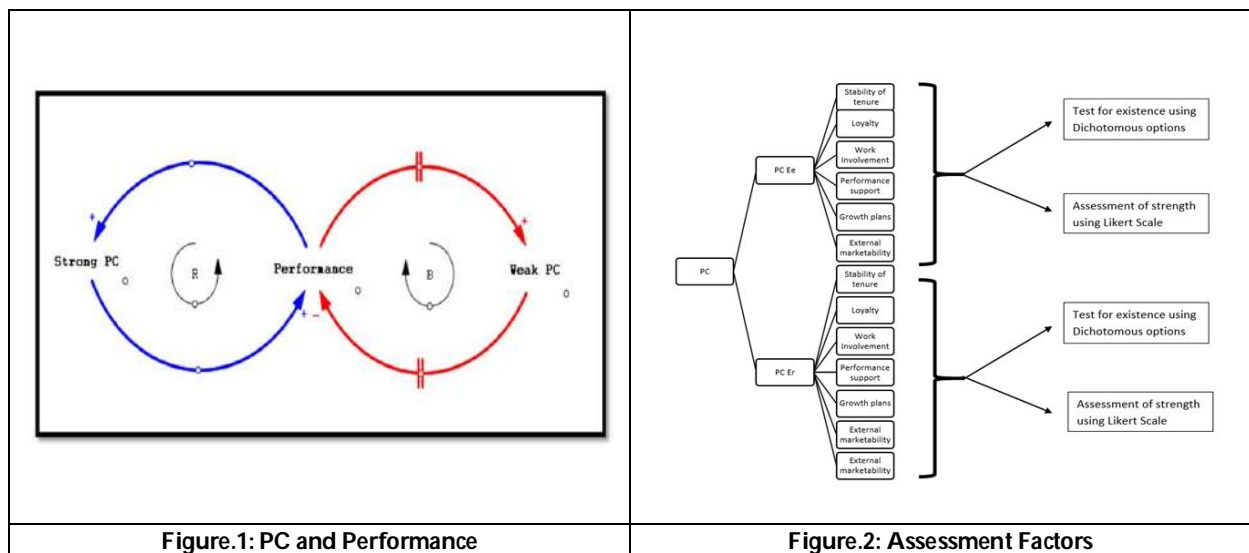


Table.8: Hypothesis 6

ANOVA Table ^a			Sum of Squares	df	Mean Square	F	Sig.
Q6 * Sector	Between Groups	(Combined)	3.809	1	3.809	3.278	.072
	Within Groups		202.140	174	1.162		
	Total		205.949	175			
Q12 * Sector	Between Groups	(Combined)	3.930	1	3.930	2.804	.096
	Within Groups		243.865	174	1.402		
	Total		247.795	175			

a. The grouping variable Sector is a string, so the test for linearity cannot be computed.

Source: SPSS



Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.746	0.861	13

Source: SPSS

Figure. 3: Reliability measure





RESEARCH ARTICLE

Examining the Influence of ICT on Teaching and Learning Practices in Indian Higher Education: Navigating Challenges and Opportunities

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ABSTRACT

ICTs, or information and communication technologies, are ubiquitous in many daily life facets. The usage of ICT has significantly altered business and governance practices and procedures over the last 20 years in almost every field of endeavour. ICT has started appearing in education, although its influence has not been as significant as in other domains. Education is a highly social activity, and good teachers with high one-on-one interaction with students have long been linked to high-quality education. The use of ICT in the classroom encourages more student-centered learning settings, often leading to disputes between educators and learners. Nonetheless, ICT is becoming increasingly important in education as the world swiftly shifts to digital media and information, and this importance will only grow as the twenty-first century approaches. The numerous ways that ICT has affected modern higher education are discussed in this essay, along with possible directions for further research. In addition to arguing for the importance of ICT in revolutionizing teaching and learning, the article looks at how this will affect how programs are offered and delivered in future colleges and universities.

Keywords: ICT, Higher Education, Online Learning, Online Learning Platform, ICT in Higher Education,





INTRODUCTION

Education is crucial for the advancement of society. Education promotes social norms. Good education provides new ideas, methods for implementing different technologies, and many other things that contribute to the country's empowerment in all fields. A good education is a fundamental requirement for society. Numerous efficient teaching and learning approaches are currently in use. The best method for students to learn more is through technology. This brings us to ICT's involvement in the educational field (**Desai, S. 2010**). "Information and Communication Technologies," or ICTs, are "a diverse set of technological tools and resources used to communicate, as well as to create, disseminate, store, and manage information." In every aspect of life, the world is quickly changing these days. Darwin's "theory of survival of the fittest" states that only individuals who change over time will survive; this idea applies to individuals and educational systems, like universities, colleges, and other educational institutions (**Shende, n.d.**). ICT has had a significant impact during the last two or three decades. These fields now function much inversely from how they did in the past. However, education appears to have seen significant development and influence compared to other industries. The number of Indian universities today provides the level of education insight into the country's emphasis on the higher education system. According to the most recent data from the UGC website, "As of February 2017, there were 789 universities, 37,204 colleges, and 11,443 stand-alone institutions in India". By now, these figures would have only gone up. The Indian government has embraced ICT and developed a national ICT strategy that many ministries and departments within the government implement. It is being carried out by the National Informatics Centre (NIC) with great enthusiasm and support from the "Department of Science and Technology" (DST), "University Grants Commission" (UGC), and "All India Council of Technical Education" (AICTE) across the country. In addition, the "National Association of Services and Software Companies" (NASSCOM) has taken on a crucial role in developing these strategies. ICT advancements have been incorporated into higher education systems worldwide within the past two decades (**Das, 2019**).

REVIEW OF LITERATURE

Over the past fifty years, higher education institutions have expanded significantly to meet the need for universal access to high-quality education. This phenomenon has been accelerated by rapid improvements in Information and Communication Technology (ICT). The demand for professional and competent labour continuously grows in today's globalized society. In light of this, it is now essential for promoting economic growth and development that everyone has access to high-quality higher education. To improve access to higher education and reach the nation's most remote regions, open and distance learning facilities are playing an increasingly important role. Furthermore, it caters to individuals' desires for lifelong learning while maintaining an accessible price. "Information and Communication Technology" (ICT) refers to various communication tools and applications, such as satellite systems, computers, television, radios, cell phones, network hardware and software, and more. It also includes the services and applications related to these devices, such as videoconferencing and distance learning. ICT can be seen as a subset of Educational Technology when it is employed to enhance student learning, build learning environments, and support educational objectives. Higher education makes use of ICTs for several reasons, including the creation of course materials, the delivery and sharing of content, the facilitation of communication between students, instructors, and the outside world, the creation and delivery of lectures and presentations, academic research, and administrative support for tasks like student enrolment (**Glorythemes.In & Glorythemes.In, n.d.-b**). Several studies demonstrate the importance of incorporating technology into teaching methods and imply that doing so enhances learning for both instructors and students (**Salam et al., 2019**). Integrating information and communication technology (ICT) in higher education is accelerated by the growing use of educational technologies. ICT integration standards and criteria evolve along with digital settings. Although there has been much focus on developing an ICT-enabled teaching and learning environment. Therefore, it is challenging to evaluate the degree of ICT integration and its effects at an institution. Thus, this paper aims to outline an ICT integration standard that can serve as a trustworthy instrument or reference in higher education (**Zhang et al., 2022**). According to **Oliva-Córdova et al. (2021)**, the use of technology in



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the classroom facilitates student learning; nevertheless, the effectiveness of this use of technology is typically dependent on the technological and pedagogical competencies of the teachers. Numerous studies have shown how crucial these teacher qualities and knowledge are to effective teaching methods. Information and communication technologies (ICTs) are now a part of every area of life, and technology has permeated every facet of civilization. After over 20 years of ICT use, almost all government and large commercial sectors have drastically changed. Since teaching is a profoundly social profession, good teachers with a strong sense of personal connection with their students have long been linked to successful learning outcomes. Higher education may now offer more student-centered learning environments thanks to ICT. Nonetheless, the significance of ICT in higher education keeps growing as digital media and information continue to permeate every aspect of our life. Every nation's progress in developing its human resources (HR) is greatly aided by its higher education system; an educated populace will promote social progress, economic stability, and peace. In most developing countries, the usage of ICT supports education reform goals (S. Kumar et al., 2023). Technology integration in educational institutions has evolved into a game-changing strategy that uses digital tools and applications to improve instruction. Introducing technology in many fields, including education, has brought significant changes. Technology integration in educational institutions is a transformative rather than merely additive shift (Higher et al., 2024). Although there may be specific difficulties and restrictions, research has demonstrated that it positively impacts student engagement and learning results (Bates, 2019). Furthermore, systematizing an effective online education program requires properly integrating ICT. ICT successful applications increase student satisfaction and assist individuals in achieving their goals (Cervero et al., 2020). Thus, the case emphasizes how important it is to integrate technology into the classroom. Though teachers and students are accustomed to using conventional technological teaching aids like PowerPoint and Smartboards when utilizing information, communication, and technology (ICT) in the classroom, their employability in the real world is still necessary for teaching methods (Akram et al., 2021).

Objective of the Study

- To examine the role of ICT in Higher Education.
- To assess the advantages and difficulties of integrating ICT in higher education
- To evaluate the advantages of using ICT in Higher Education.
- Identify the ICT initiatives in Indian Higher Education.

METHODOLOGY

The methodology employed for this literature assessment involves a methodical exploration of scholarly research databases, online resources, and journal content listings. Additionally, pertinent web pages are also examined. Additionally, when applicable, online reports, conference papers, and theses have been considered.

Benefits of ICTs in Higher Education

Adoption and integration of technology in education have a favorable impact on learning, teaching, and research. Additionally, it improves flexibility and offers a stimulating environment and inspiration for the teaching and learning process, significantly impacting learning by creating new opportunities for teachers and students. These options may affect the success and performance of the students (Dahiya, B.P., 2018). The different ways that ICT in education serves various stakeholders are:

Students

- Increased Access to multiple learning materials.
- Deliver flexible content.
- Combine the work and education.
- High quality of education with qualitative interaction.



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- Upgrade teaching skills and increase productivity.
- Establish a new learning environment.
- Share knowledge and thoughts with the discussion forum.
- Increased the training duration.

Governments

- Boost the effectiveness and capability of the structures for education and training.
- To ensure curriculum and instructional facilities are linked to the new information resources and networks.
- To support and improve the existing educational structures' quality and relevance.
- To promote development and opportunities for lifelong learning

Challenges of ICTs in Higher Education

The educational sector faces some challenges while implementing ICT in the education system. The barriers are stated below:

- Non-availability of buildings, electricity & Communication infrastructure for implement ICT.
- Lack of proper funding for buying ICT equipment.
- Lower bandwidth capacity than developed country.
- One of the most prevalent challenges is a language barrier. An estimated 80% of online learning platforms are in English. Most of the educational software developed in the global market is in English. However, it is exceedingly challenging to implement in developing nations like India, where there is a low level of English proficiency, particularly in rural regions.
- A broad lack of awareness regarding ICT. Individuals must adopt an emerging approach and support emerging technologies to advance their academic pursuits.

Growth of ICT in Higher Education Systems

ICTs are rapidly contributing to many metrics inside the Indian higher education framework. Radio, television, and audiovisual aids are used in broadcasting and education. The "University Grants Commission" (UGC), with the "Consortium for Educational Communication" (CEC) serving as the nodal office, established "Educational Media Resource Centres" (EMRCs) and "Audio-Visual Resource Centres" (AVRCs). The Eleventh Five Year Plan established a "National Mission in Education" through ICT, further promoting the use of ICTs in education. In this sense, using ICTs would significantly improve educational Access and quality, but it could also lead to circumstances. Even though the expansion in numbers is not the qualitative revolution that was hoped with the launch of new services and better training with learning materials, it has effectively reached many people (Saleem, S. 2012). A "National Mission in Education" through ICTs is scheduled to be launched in the higher education sector to expand "ICT coverage in all 789 universities, 37,204 colleges, and 11,443 stand-alone institutions in India". The Mission will prioritize the development of low-cost, low-power access devices, networking and digitizing all educational institutions, and providing bandwidth for educational purposes (Sarkar, S. 2012). According to a November 2020 survey, web-based apps, software applications, big data, and web-based apps were the technologies most frequently utilized by well-established educational organizations. The development of portals allowing students to be examined and evaluated based on multiple criteria, a component of distance learning, contributed to the expanded use of information technologies. The quantity of online education users has shown substantial growth since 2017. Throughout the COVID-19 epidemic, the number of users who experience online education products has increased, surpassing that of prior years, primarily attributed to an increase in the number of Individuals utilizing online educational systems. In 2019, there were approximately 429 million. Individuals utilizing educational media increased to 565 million in 2020 and 651 million after that. This fast growth of the sector has diminished in the wake of the pandemic. However, the consistent increase in users across all internet platforms and Learning products refers to the aggregate. The number of e-learners is projected to increase more than threefold from 2017 to 2025, reaching approximately 1.1 billion users by 2028. For 2022 to 2027, this translates to a compound annual growth rate (CAGR) of more than 10% annually, or nearly 14% if the years following 2017 are considered.



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The online university sector has contributed to overall revenue growth in the online education industry; however, online learning platforms exhibit a significantly higher penetration rate, exceeding 10 percent in 2024, while online universities remain below one percent. The penetration rate quantifies the adoption of a product or service relative to the total potential market for that offering. The overall penetration rate for online learning goods increased from approximately four percent in 2017 to over ten percent in 2024. The proliferation of online learning platforms surpasses traditional university education and professional certifications, indicating that the online university education sector, specifically, possesses considerable potential for future expansion.

ICT Integration of Higher Education in India

"Information and communication technology" (ICT) integration in Indian higher education has profoundly affected many facets of the learning environment. These are some significant ways that ICT has involved Indian higher education. India, the fourth largest market for online education worldwide, derives a significant portion of its e-learning users from the information and telecommunications, professional, scientific, and technical services, as well as the education and healthcare sectors. According to pages 14 and 28 of this research, Indian e-learners predominantly belong to a younger demographic, with 40 percent identified as Generation Z.

E-Learning Platforms

Education has become more accessible with the introduction of e-learning platforms. Students can now attend courses from leading universities and institutes worldwide by removing geographical boundaries. Some of the E-Learning platforms are popular in India.

SWAYAM

To achieve our educational policy's three primary objectives—equity, quality, and accessibility—the Indian government introduced the captivating SWAYAM site. SWAYAM's main objectives are to bridge the digital divide and offer online learning. It provides many free courses for remote Access for graduate, postgraduate, and school education. Figure 8 describes the number of courses launched from 2014-2019.

- **Swayam Prabha:** Despite the prevailing lockdown, Union HRD Minister "Ramesh Pokhriyal Nishank" took a significant step when the MHRD began offering online classes to students on Swayam Prabha DTH channels. Students can choose a time slot that works best for them each day by accessing four hours of newly created content on Swayam Prabha DTH channels. This content is then repeated five more times during the day. Using the GSAT-15 satellite, a subscription service includes 40 DTH channels. Swayam Prabha's content partners include eminent educational institutions, including "NPTEL, IITs, UGC, CEC, IGNOU, NCERT, and NIOS."
- **National Digital Library (NDL):** It is a digital repository with a significant amount of scholarly literature available in several formats. It supports major Indian languages for the interfaces. It is appropriate for students, researchers, and lifelong learners at all academic levels (Mondal, D., 2021).
As per the NDLI website, the number of documents increases daily.
- **MOOCs:** All users can access free online education through Massive Open Online Courses (MOOCs). MOOCs provide students with the opportunity to grow professionally, acquire new skills, and participate in extensive educational experiences in a flexible and affordable way. Millions of learners across the world utilize MOOCs for a variety of learning goals, including corporate eLearning, training, supplemental education, career transitions, job progression, higher education preparation, and more.
- **E-PG Pathshala:** It offers almost Twenty-Three thousand e-text and video courses covering seventy postgraduate disciplines in the social sciences, fine arts, arts, humanities, natural and mathematical sciences. It is an excellent curriculum-based, interactive online platform for online resources.
- **E-Sodh Sindhu:** It offers Access to over "15,000 peer-reviewed core journals" and archival material in various disciplines. Its member institution has access to "bibliographic, citation, and factual databases" from multiple publishers and aggregators. The "centrally funded technical institutions, universities, and colleges covered by the UGC Act" are among these establishments.



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- **NPTEL:** The "National Program on Technology Enhanced Learning" was started by the Indian Institute of Science, Bangalore, and seven IITs: Madras, Guwahati, Kanpur, Delhi, Kharagpur, Bombay, and Roorkee. This platform makes it easier to access video lectures in the engineering disciplines in the following five: electrical, electronic, computer, civil, and communication engineering.
- **LMS:** The learning management system is an application program. It helps track, report, automate, and manage the provision of training courses and programs. It offers both teachers and students a variety of advantages. Additionally, there are discussion forums where students can post questions and engage in class debate. Some LMS softwares are Talent LMS, Moodle, 360 Learning, and others.
- **VIDWAN:** VIDWAN is an online database that provides information about researchers and faculty members in the higher education institutions of India. It includes details about their academic qualifications, research interests, publications, etc. The database serves as a resource for academic networking and collaboration.
- **Shodh Ganga:** Figure (Fig 10) depicts the trend in thesis submissions on Shodhganga, an Indian repository of theses, from 1924 to 2024. The number of theses submitted is shown on the Y-axis, while the X-axis shows time in decades. The data shows an exponential growth trend in thesis submissions over the century. From 1924 to 1959, the numbers were relatively low in the early years, starting with only two theses between 1924-1929 and gradually increasing to 1162 by 1950-1959.

However, from 1960 to 1989, there was a moderate increase, with submissions rising from 4347 (1960-1969) to 21,191 (1980-1989). A sharp rise is observed from 1990 onwards, with the numbers escalating significantly: 30,774 theses in the 1990s, 62,163 in the 2000s, and an impressive 186,283 in 2010—the most recent period, although it still represents a high volume of submissions. The graph shows the overall exponential rise of thesis submissions, with a dashed trendline and blue bars representing the data for each decade. This pattern shows a significant increase in scholarly research activity in India, especially in the last several decades, probably because of the growing emphasis on research projects and higher education. The distribution of thesis submissions in Indian academia is depicted in the TreeMap and statistical data, with 76,584 theses in the social sciences ranking as the most popular field. Engineering and Technology (50,931), Arts and Humanities (45,828), and Physical Sciences (45,763) all show notable contributions. Computer science, economics, and life sciences are other well-known disciplines. The Tree Map visually emphasizes the more significant proportion of Social Sciences and Engineering disciplines, with smaller segments representing emerging fields like Clinical Medicine, Economics, and specific branches of Engineering. This visualization underscores the diverse research focus areas and the substantial growth in higher education research output, reflecting a robust academic ecosystem in India.

CONCLUSION

ICT is exceptionally beneficial to education. Emerging and new technologies challenge the conventional teaching and learning process and education management. Integration of ICT into education is crucial for enhancing the effectiveness and quality of education. In general, implementing ICT has changed the activities of higher education institutions and universities. In the modern, technologically sophisticated world, the importance of ICT in education and ICT sufficiency as a social necessity has been increasing. Information and communication technologies must be socially acceptable to increase public mobility, social equity, and pitch for value. In the given context, education has been acknowledged as a service that must be expanded to facilitate unrestricted trade worldwide. Using ICTs in contemporary education can significantly reduce government expenditures. Furthermore, significant qualitative progress can be observed when the training resource personnel are of the highest standard. The integration of ICT across multiple educational phases has the potential to enhance academic quality and standards. However, inadequate educational sector resources impede the implementation of ICT in developing nations in the 21st century. In the goal of sustainable development, higher education institutions can be seen as significant community members and role models. In addition to critically analyzing the learning environments and procedures that students go through, higher education should consider its part in building the framework that facilitates and supports lifelong learning. The widespread use of ICT necessitates the development of flexible mindsets and skill sets. Higher





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education's use of ICT changes how teachers and students learn and foster the development of higher-order abilities like problem-solving and cross-platform collaboration. In order to reap the full benefits of ICT in education, a few questions must be answered: Why do teachers use technology? How can ICT be implemented effectively? What are the prerequisites for successful ICT implementation? Studies have revealed that instructors' knowledge, in particular, is one of the significant factors influencing the success of ICT implementation. Teachers must adjust to ongoing professional development regarding the use of technology in the classroom. The numerous stakeholders must have a shared vision, and a cooperative strategy must be used. All stakeholders' attitudes and beliefs need to be carefully influenced. In order to provide accountability, quality assurance, accreditation, and consumer protection, appropriate controls need also be made. Education will eventually become more democratic as a result of ICT-enabled learning. ICT, or "Information and Communications Technology," is a general term for devices and services for information management and dissemination. Televisions and cell phones are significant examples of ICT in education. Our daily lives and educational fields involve extensive use of ICT, which has become necessary daily. "ICT in education includes presentations, audio, videos, images, and a combination of these for educational instruction." Therefore, "ICT in education" refers to using "Information and Communication Technology" to enhance education delivery.

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Table:1

Particulars	2016	2017	2018	2019	2020	2021
Number of Content hosted on the NDLI website	1485168	6423499	16191515	27814879	48184251	64651364

Table 2: E-PG Pathshala Subject Modules

Subject	No Uploaded Module
Library Science	395
Chemistry	565
English	560
Anthropology	559
Economics	567
Forensic Science	560
Commerce	469
Law	462
Geography	337
Sociology	526
Management	599
Mathematics	567
Political Science	222
Psychology	599
Computer Science	633
Hindi	592
Environmental Sciences	530
Geology	136
Indian Culture	524
Social Work Education	487

Table 3:ShodhGanga Statistics

Subject	No.	Subject	No
Social Sciences	76584	Language and Linguistics	12121
Engineering and Technology	50931	Plant and Animal Science	12084
Arts and Humanities	45828	Arts and Recreation	11910
Physical Sciences	45763	Engineering Electrical and Electronics	11175
Life Sciences	39520	Mathematics	10885
Social Sciences General	34832	Biology and Biochemistry	10273





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Engineering	31711	Economics	9042
Economics and Business	28766	Education and Educational Research	7792
Chemistry	21517	History and Geography	7105
Literature	19726	Engineering Mechanical	7053
Computer Science	16961	Clinical Medicine	6693
Management	13879	Physics Applied	6490
Language	13675	Agricultural Sciences	6225
Physics	13494	Chemistry Applied	6119
Clinical Pre-Clinical and Health	12311	Zoology	5827



Figure 1: ICT in Education

Source: <https://publications.chitkara.edu.in/importance-of-ict-in-education-for-gifted-students/>

Size of the global e-learning market in 2019 and 2026, by segment (in billion U.S. dollars)

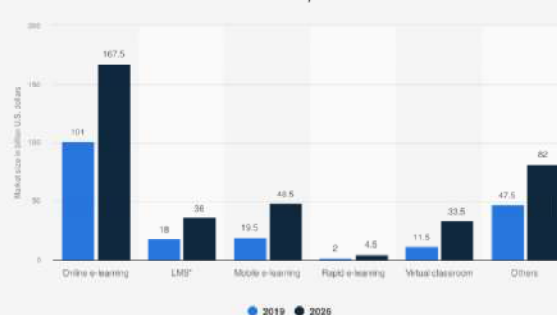


Figure 2: Global E-Learning Market

Source: <https://www.statista.com/statistics/1130331/e-learning-market-size-segment-worldwide/>

Technologies used by established companies in the education sector in India in 2020

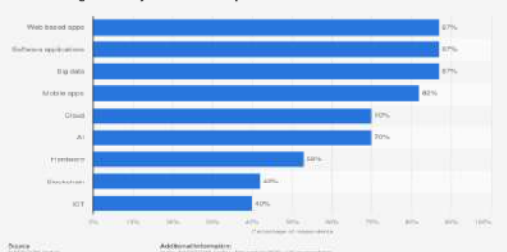


Figure 3: Technology Used by Companies

Source: NASSCOM (India) Statista 2024

Number of users (in million)



Figure 4: Number of Users Enrolled

Sources: Statista Market Insights





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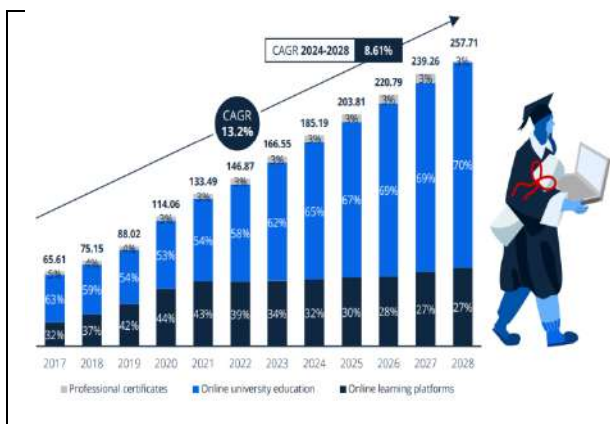


Figure 5: Trends of Online Learning Sources: Statista Market Insights

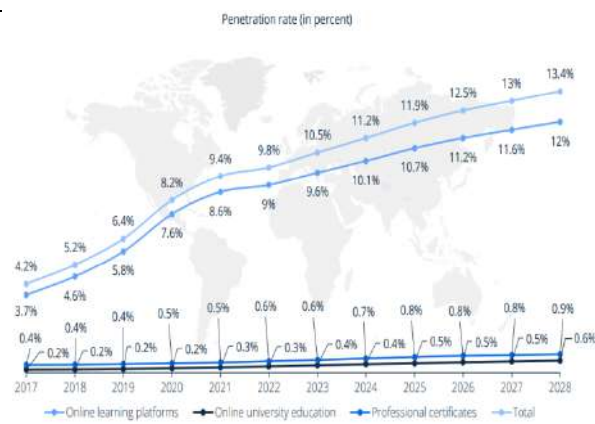


Figure 6: Technology Used in the Indian Education System Sources: Statista Market Insights



Figure 7: ICT Integration in India Source: Statista Consumer Insights

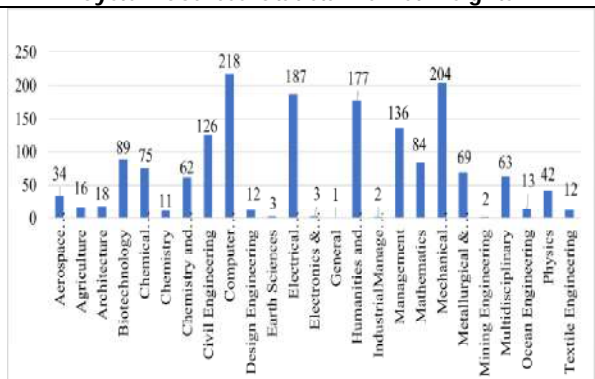


Figure 8: Course Conducted by Swayam from 2014-2019 Source: Authors own work

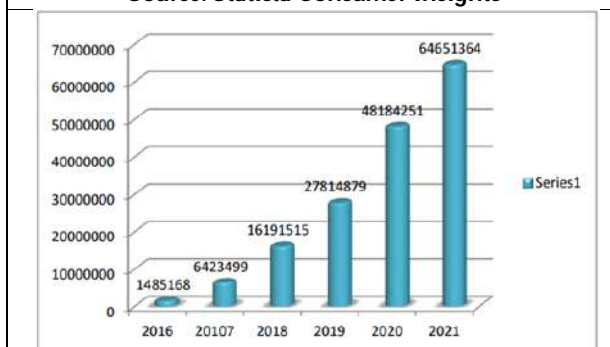


Figure 9: NDLI Resource Statistics 2016-2021 Source: Authors own work

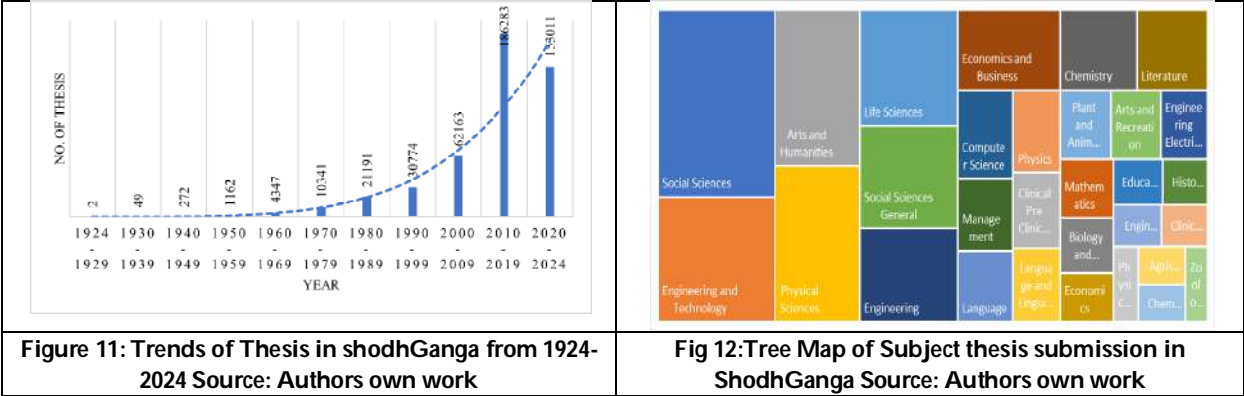


Figure 10: Trends of MOOCs Course Source: Class Central





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RESEARCH ARTICLE

Deteriorating Assets Quality and its Impact on Wealth Creation of Shareholders with Reference to SBI

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ABSTRACT

Maintaining healthy financial system is very essential since banking sector represents a major chunk of nation economic growth, it is considered as an integral part of financial system. The bankruptcy of Silicon Valley and Signature bank crash biggest a big surprise for its clients in US history. SBI is one of the largest PSU after RBI, having over 22,405 branches throughout world. An international firm, Price water house Coopers reported that, India will be 3rd largest major financial center till 2040 on the other hand its finance and technology sector is projected to reach Rs 6.2 trillion by 2025. SBI is the only bank coming under the umbrella of top 50th place compared to all other nation. A key issue confronted by banking sector is NPAs. Government banking sector in India reported a total of 1.9 trillion rupees in net NPA by 2022-23. Consequently it is most significant to analyze the damage caused by NPA on these variables to assess impact on banking sector development.

Keywords: : Economy, EPS, Dividend, NPA, SBI and Growth of country.

INTRODUCTION

It has been observed that mounting and deteriorating quality of assets became a threat for Indian banks. In one way the merger supported by the RBI and Government to overcome the situation of worst NPA of SBI but another way it created the lot of internal and external pressure on the Stakeholders. By Inculcating technology economy can be



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upgrade the banking sector, in this regard steps needed to lay down a strong base but in India most of the banks are in misery because of the increase in NPAs which directing towards loss at the same time creates difficulty to maintain regular work. It will lead to bad impression on its customers and entire banking industry hence creates panic among the investors which is not in the interest of the growth of economy. Majority of the government banks are suffering with huge crisis of deteriorated asset quality, one stop solution for this issue is "merger or liquidation". Banking sector in India going transformation through digitalization process on the other hand rising non performing asset impacting badly on development of Indian economy, it is need of the hour to study the significance of nonperforming assets to forecast the prospect growth of banking sector in India.

Statement of problem

SBI must take a strong decision regarding its extremely rising NPA. This decision was taken after discussion with the department finance government of India in order to protect interest of its stakeholders. This situation is considered as a distressing sign for economy as a whole. After bringing all its ancillary banks under one umbrella, it has been observed that there is decrease in proportion of nonperforming assets. Even after this PSU banks are unable to forecast the impact of deteriorating asset quality. In this regard a sincere attempt has been made to evaluate the impact of nonperforming assets on stake holders.

- To evaluate the impact of deteriorating asset quality of select bank for the study.
- To analyze the impact of nonperforming asset of its stake holders.

Hypothesis

H0: There is no association between profitability, provision for NPA, EPS and DPS on Net NPA.

RESEARCH METHODOLOGY

The present research work is investigative and descriptive. Both types of data collected first hand information and also the data which is available in public domain has been collected for research. Primary data collected through structured interview bank officials and secondary data collected from the websites. To analyze the data, percentage, mean, standard deviation, correlation, regression analysis, provisions with respect to bad and doubtful assets, earning per share, dividend per share of select bank is taken in to consideration.

REVIEW OF LITERATURE

- **Research conducted by kumar das also utpal-** The study found that Asset quality of bank declining and its influence on ROA specifically commercial banking in Indian context by following "random effects method also it comprise wealth as essentials like rise in "GDP" level in development perspective.
- **Kumar et al. (2018)** His study found that main causes after multiplying bad assets. Identified causes for business illness, transformation of strategy statutory bodies, improper assessment of credit mechanism, intentional non-payment at the same time defective lending system.

Gap topic on the study

After having a glance on above literature it shows that only few studies are done on present topic of our research field. The present context research identifies contributing factors towards NPA threat in the banking space. The topic of study proves to be value addition to the banking literature after some point of time considering even geographical region and it will help in understanding economic constraints of financial institution or entire banking industry.

Drawbacks of the study

- It confined with respect only on non performing assets with respect to SBI only
- The time and resources allotted for the study were not sufficient.





- Findings and suggestions of the study cannot be generalized with other banks.

The above table depicting the year after year net income and provision for nonperforming assets of SBI considered 2013-2014 was base year, it can be identified that portion of income distributed for provision was increasing from 2013-14 to 2018-19 that is 26% to 94% after that from 2019-20 to 2022- 23 it was declined from 62% to 12%. From the above table it can be inferred that provision made for NPA, EPS and DPS, it is clearly showing that maximum of provision on NPA is in the year 2018-19 during the period amalgamation and merger which severely influenced the EPS and DPS i.e. negative EPS up to -7.67 and DPs of Nil and minimum of provision is maintained in the year 2013-14 leads to high EPS of 210.06 and DPS of 41.5. Above table exhibits the changes in the P/E Ratio of shareholders of SBI over 10 years, it can be observed that due to decrease in both EPS and share price leads to sustain a similar price earnings ratio. In the year 2018-19 during merger the shareholder are getting negative P/E ratio and in the year 2013-14 highest of 10 percentage P/E was benefited from by the shareholders wealth creation. As per descriptive statistics table Net NPA is amounts to rupees 48781.200, net interest income is amounts to rupees 76038.70 in corer, Provisions for NPA is rupees 31204.70 corer, earnings per share 14.852 and also dividend per share is rupees 2.70 per share. Standard deviation varying from 26577.30 i.e. net NPA till dividend per share 2.259, earning per share is 11.7536. And provision for NPA standard deviation 19500.603 by having glance on all statistics there is immense variation according to descriptive data. Above statistical test of Pearson correlation shows that there is significant association between profitability, provision for NPA, EPS and DPS on Net NPA. Further from table @5%significance the calculated value is more, compared to table values thus the H0 hypothesis rejected alternative H1 is accepted. Since calculated value is more than table value @0.05% significance null hypotheses rejected, H1 alternative hypothesis accepted, therefore it is agreed that there is a significant association between profit, provision, earning per share and dividend per share on net nonperforming assets. And the R squared value is 0.952 forecast stage. Hence calculated value F is 0.201 is more than table value @0.05% significance compared to table value which is 0.666 hence H0 null hypotheses rejected, H1 alternative hypothesis accepted.

Findings

1. Since it is noticed that net NPA on loans and advances enhanced during 2018-19 after the impact of merger it was started reducing i.e. 2019-20 to 2022-23 up to 405% till 27%.
2. According to the observation net NPA it was not reducing and hence due to increase in the provision of NPA heading to show reduction in the net nonperforming assets.
3. Even it is observed compared to total loans and advances, total deposits are enhanced very fast.
4. Since there is negligence from banks there is an association between total advances, net profits and NPA of bank.
5. It was identified that profits circulated to the equity shareholders reduced to ensure enhance the provision of nonperforming assets and capital adequacy.
6. Together attention of the investors towards State Bank of India an important step has been taken to reduce the face value of shares.
7. As per the observation a vital impact on profit, provisions, earning per share, dividend per share on net nonperforming assets i.e. up to 0.952 extremely expected but co-linearity between the independent variables somewhat have control in making decisions.
8. Study also noticed no momentous effect on net nonperforming assets on equity share price of shareholders which not at all acting wisely to enhance nonperforming assets.
9. Also there is no positive association between the provision on nonperforming assets on earning per share and dividend per share even after raise in profit.
10. Even after increased provision with respect to NPA's stake holders unable to get proper dividend per share and also justify ably revenue.



**Jagadish and Shivakumar****Suggestion**

1. Constant observation needed to ensure on customers and client's credit worthiness.
2. CIBIL and credit score has to be restructured frequently with in a specific time frame.
3. Additional guidelines prescribed by RBI to be adopted before granting loans.
4. Specific limit has to be prefixed before granting loans and advances in both context i.e. secured and unsecured loans.
5. Effective measures must be taken to enhance long term deposits from clients and customer in tern it leads generation of income.
6. A separate department must be taken the responsibility of NPA and Its Updates consistently.
7. Management must implement Basel III in order to ensure decrease in the level of NPA.
8. Government regulations and RBI provisions compulsorily followed properly to reduce NPA from willful defaulters.
9. Constant dividend pay-out ratio and EPS declarations will increase the shareholders confidence it leads to increase in share price and attracts more investors.
10. Focus should be given to investments rather than lending of loans to control the NPA
11. There are number of key issues liable for weak performance of banks, the main portion of the income proportion of bank are in misery.
12. Proper financial forecasting is needed form the point of profitability and liquidity needed to be verified accurately.

CONCLUSION

Research on the topic of our study considering it as key aspect i.e. NPA's to ensure the firmness banking sector. India is fastest growing digitalized economies in the entire world. In upcoming days everything is involved with banking sector. A strong foundation is essential to meet the emerging requirement of not only engineering but also reengineering things. Still a long journey is ahead, to maintain image of banking sector and also enhance the confidence among common citizens in India. Through the research it is observed that the influence in high NPA on growth of banks with reference to SBI. Through this study it is observed that still SBI is lacking behind to overcome from NPA to meet the expectation of wealth creation. SBI must adopt the responsibility accounting and it should fix time limit.

Scope for further study

An attempt in Elimination of NPA's in Banking Sector with the interface of AI.

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Year	Net Interest	% Change in interest	Provision for NPA	% Changes NPA	% of provision in net income
2013-14	44,329	0	11,368	0	26
2014-15	49,282	11	14,224	25	29
2015-16	55,015	24	17,908	58	33
2016-17	57,195	29	26,984	137	47
2017-18	61,860	40	32,247	184	52
2018-19	74,854	69	70,680	522	94
2018-20	88,349	43	54,529	380	62
2020-21	98,085	121	42,776	276	44
2021-22	1,10,710	150	27,244	140	25
2022-23	1,20,708	172	14,087	24	12

Table 2: Provision of NPA, EPS and DPS

Year	Provision for NPA	EPS	DPS
2013-14	11,368	210.06	41.5
2014-15	14,224	156.76	30
2015-16	17,908	17.55	3.5
2016-17	26,984	12.98	2.6
2017-18	32,247	13.43	2.6
2018-19	70,680	-7.67	00
2019-20	54,529	0.97	00
2020-21	42,776	16.23	00
2021-22	27,244	22.87	4
2022-23	14,087	35.49	7.1

Table 3: Showing profit earnings ratio of shareholders P/E Ratio – Percentages

Year	Earnings Per Share	Share Price	P/E Ratio
2013-14	210.06	2,072.75	10
2014-15	156.76	1,917.70	8
2015-16	17.55	267.05	7
2016-17	12.98	194.25	7
2017-18	13.43	293.4	5
2018-19	-7.67	249.9	-3
2019-20	0.97	320.75	0
2020-21	16.23	196.85	8
2021-22	22.87	364.3	6
2022-23	35.49	493.55	7





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Table:4 Descriptive statistics of above data

Particulars	Mean	Std. Deviation	N
Net NPA	48781.200	26577.2942	10
Net Interest Income(in corer)	76038.70	26989.657	10
Provisions for NPA (in corer)	31204.70	19500.603	10
Earnings Per Share	14.8520	11.75366	10
Dividend Per Share	2.70	2.259	10

Table 5: Showing correlations

Particular		Net NPA	Net Interest Income	Provisions For NPA	Earnings PerShare	Dividend Per Share
Pearson Correlation	Net NPA	1.000	.055	.940	-.861	-.729
	Net Interest Income (in corer)	.055	1.000	.216	.304	.151
	Provisions for NPA	.940	.216	1.000	-.847	-.823
	Earnings Per Share	-.861	.304	-.847	1.000	.869
	Dividend Per Share	-.729	.151	-.823	.869	1.000
	Net NPA	.440	.000	.001	.008	
	Net Interest Income (in corer)	.440	.275	.197	.338	
	Earnings Per Share	.000	.275	.001	.002	
	Dividend Per Share	.001	.197	.001	.001	
	Net NPA	.008	.338	.002	.001	
Sig.(1-tailed)	Net Interest Income (in corer)	10	10	10	10	10
	Provisions for NPA (in corer)	10	10	10	10	10
	Earnings Per Share	10.00	10.00	10.00	10.00	10.00
	Dividend Per Share					
	Net NPA					
N	Net Interest Income (in corer)	10.00	10.00	10.00	10.00	10.00
	Provisions for NPA (in corer)					
	EPS					
	DPS					

Table:6 Test statistics

Method	Value of R	Value of R Square	Value R Square.	SD. Error with Estimation	Durbin watson
1.0	.976	.952	.914	7793.42430	02.734

Test: 7 Analysis of variance test

Value	Square	df	χ^2	Value of f	Level of Sig
Regression	6053485806.822	4	1513371451.705	24.917	.002
1 Residual Total	303687312.778	5	60737462.556		
	6357173119.600	9			





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Test:8 Different correlations

Particulars		Equity Share Price	Exact Net NPA
Pearson Correlation	share price	1.000	-.157
	Net NPA	-.157	1.000
Sig. (1-tailed)	share price	.	.333
	Net NPA	.333	.
N	share price	10	10
	Net NPA	10	10

Table:9 Analysis of variance test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2031.264	1	2031.264	0.201	0.666
	Residual	80890.111	8	10111.264		
	Total	82921.375	9			





Exploring the Integration of Environmental Sustainability in Teaching Practices among Teachers of Higher Education Institutions

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ABSTRACT

This study explores the integration of environmental sustainability in teaching practices among teachers of higher education institutions. It examines the extent to which sustainability concepts are embedded in curricula and pedagogy, and identifies challenges and opportunities for enhancing environmental awareness. Major objective of this paper is to examine the perception towards environmental sustainability awareness of in-service teachers. The researchers used a mixed methodology. Qualitative data were gathered through unstructured interviews, while quantitative data was gathered from 115 In-service teachers from the Lucknow district. For data analysis, the researcher employed the Environmental Education, Sustainability and Awareness Scale (EESAS). With the aid of SPSS software, the researcher separated the data according to the characteristics of gender, location, subject, parents' occupation, and category. The study's main conclusions are as follows: researcher found there is no difference in attitude based on gender; there is a significant difference in environmental awareness based on locale, specifically between locale areas; there is a difference in environmental awareness from the perspective of education between the suggested sectors of agriculture and non-agriculture; teachers whose parents are working in government job and those whose parents are not in government job, researchers found significant difference towards the environmental awareness. Similarly, we can say that in the category where both men and women have the same educational background, there is no difference in environmental awareness. Through this study, the researcher promotes the need of integrating environmental



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consciousness into the curriculum, promoting policy, and preparing in-service teachers to make significant contributions to society.

Keywords: Educational Awareness, Environment Sustainability, In-Service Teachers, and Higher Education.

INTRODUCTION

The global ecological issue of our time reflects how people develop ecological attitudes and orientations and how the need for ecology develops in the consciousness of the general public. In view of the global environmental problem, environmental education is necessary to lay a strong foundation for people's ecological thinking. Therefore, the main objective of ecological education is to promote basic environmental knowledge and help each individual and society to develop ecological consciousness and ecological culture (Wojtowicz,2019; Keles, 2017)). This objective will ensure that individuals develop positive thinking towards their ecological consciousness and ecological culture, which is essential for making economically correct decisions at the regional, industry and business levels. As a result, it is impossible to address contemporary environmental concerns without a positive shift in ecological consciousness. Today, the issue of how to develop ecological consciousness within an individual falls into the category of socio-psychological issues around the world (Doronina, Semenkov, & Taburkin, 2018; Machnev et al., 2018). Furthermore, basic education is crucial for the development of environmental consciousness. Starting from primary school, "abandoning destructive consumerist lifestyles and adopting frugal and restorative lifestyles" is the first step. A generation of young people who are ecologically literate and able to implement an unconventional approach to building relationships with nature must be adequately trained, as determined by society's changing educational standards, starting from primary school and progressing to higher education (Iizuka, 2016). According to the contemporary educational paradigm, the development of environmental literacy is at the core of all educational efforts, resulting in the development of environmental competence and awareness in both individuals and society (Fang et al., 2022; Roth, 1992). This task cannot be accomplished without affirming the body of constructive empirical and scientific knowledge on the relationship between nature and humans for the survival of humanity (Barth & Rieckmann, 2012).

The development and function of the environment, as well as how each individual feels about it, is largely determined by how environmental consciousness is formed, how people feel about nature, and how well their basic environmental knowledge is established during primary school, as well as how teachers in higher education are playing their vital role in environmental awareness. Thus, developing ecological awareness in aspiring higher education teachers is crucial to their training in higher education institutions and is a key driver of the ecological culture of global youth (Lugg, 2007; Chankseliani, 2021; Haigh, 2013). These important global challenges will be the main focus of our study. It becomes very important to develop environmental awareness among teachers and to find out the extent of their awareness (Labog, 2017). Thus, this paper examines the primary aspects of this issue. Specifically, the researcher has attempted to make a comparative study on the basis of: gender, category, and subject of teachers and the nature of the job of the parents of the teachers as well as the education of their parents. This study aims to investigate the current state of environmental sustainability integration in teaching practices among higher education teachers, focusing on their perceptions, challenges, and strategies (Ramisio, 2019). Understanding these dynamics is essential for identifying gaps in teacher preparation and support, which can inform policy and curriculum development (Huisin et al., 2015). This study aims to advance effective teaching strategies that enable students to critically engage with sustainability issues and to add to the growing body of knowledge on education for sustainable development (ESD) by investigating how educators manage the challenges of incorporating sustainability. In the end, encouraging a sustainable culture in higher education can improve instruction and equip students to handle the complex problems of the twenty-first century (Bell, 2016; Zusman, 2005).





REVIEW OF RELATED LITERATURE

The Researchers have conducted several studies in this area, emphasis on in-service teachers' environmental literacy, their attitudes toward sustainability, and pedagogical strategies that promote sustainable development. This study purpose to provide insights into these issues and propose potential future directions to enhance environmental education in India, address existing gaps, to promote a more successful inclusion of environmental consciousness into higher education's curricula. Towards this end, the researcher studied the paper by Kumar, J. A. (2012) aimed to study the perception of teacher candidates about the environment in teacher training institutes in Tiruchirappalli district of Tamil Nadu Survey methodology was adopted. For data collection, 300 prospective teachers were selected from the institutions of the district through simple random sampling. A questionnaire was designed by the researcher to measure environmental awareness, and statistical techniques such as variance analysis, correlation analysis and percentage analysis were used to analyse the results. The main findings indicate that teacher trainees have an average level of environmental awareness, with no significant differences observed based on variables such as gender, locality, or teaching ability. According to Nagara, V. and Singh, S. (2013), In their study explores environmental education awareness of senior secondary school teachers by examining factors such as school type, gender and subject streams. Data was collected through an environmental awareness assessment conducted with a random sample of 200 teachers. The researcher adopted statistical methods such as standard deviation, t-test, and mean for data analysis. The results showed that educators generally demonstrated an average level of awareness of environmental education. Additionally, the analysis showed no significant differences in environmental awareness related to school type, gender, or subject area. Padmanabhan, J., Borthakur, A., & Mittal, K. (2017) In this study, the United Nations Decade of Education for Sustainable Development (UNDESD) highlighted the critical need to incorporate environmental education in both school and teacher education curricula. This integration is deemed essential to promote develop positive and environmental awareness attitudes towards environmental protection. The aim of this study was to study the level of environmental consciousness among higher education instructors and students enrolled in the Orientation Programme (OP-123) at Human Resource Development Centre (HRDC), Himachal Pradesh University, and Shimla.

A survey instrument covering topics such as biodiversity, water resources, sanitation, health and climate change was designed. The findings revealed that teachers displayed a high level of awareness towards the environment while 64.28% of students showed a deep awareness about environmental issues. The study also provides recommendations for protecting the environment. Nazarenko, V. A. (2018), this paper presents innovative approaches to professional environmental training for future educators, focusing on the development of environmental awareness. A model of environmental awareness was created and applied in a pedagogical experiment to highlight its importance in the broader context of professional competence for future ecologist specialists. The study involved 47 students of a pedagogical university, assessing their theoretical knowledge and environmental skills. The educational process was skilfully designed to encourage the development of environmental awareness and attitudes by using a variety of training techniques and drawing on real-world experiences. The original techniques used stimulated students' intellectual involvement in environmental issues, allowing them to identify and activate their personal potential in areas such as nature and resource management, as well as environmental protection. Jayagandhi, T. and Suganthi, M. (2019), this paper purpose to examine the environmental consciousness of student-teachers from education and training institutions in the Madurai region. A random sample of 72 participants was selected for the study. Data was gathered through an environmental awareness questionnaire developed by the researcher, and analyzed using statistical methods such as standard deviation, t-test, and mean. The findings indicated that the majority of student-teachers possessed a moderate level of environmental awareness. Additionally, there is no significant difference was found in environmental awareness based on factors such as gender, age, and locality, educational qualification of parents or annual income. The conclusion suggests that there is a need to increase environmental awareness among student teachers and the role of teacher educators should be emphasized in promoting this awareness for the betterment of the society. Turan, E. Z. (2019) this study found that there is a need for teachers to make students more aware of the environment and develop sensitivity towards environmental challenges. The purpose of this study was



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to assess the environmental sensitivity and awareness of teacher applicants. The research used "environmental awareness and environmental sensitivity" scale developed by Timur and Yilmaz (2003) to collect data from 277 teacher candidates. The data was analyzed using descriptive analysis with the SPSS program. The findings show that there is no significant difference in environmental awareness or sensitivity based on the candidates' gender or specific teaching branch. However, a significant variation was observed in the environmental sensitivity dimension among different branches. Gender did not affect the level of environmental awareness or sensitivity of teacher candidates. In particular, candidates specializing in religious culture and ethics teaching displayed higher scores in environmental sensitivity than those in other branches. These results suggest that environmental sensitivity may vary across teaching subjects, with some fields showing a greater inclination towards environmental issues. (Corpuz, 2022) Study was conducted on the topic "Integration of Environmental Education in Teacher Education Programs: Towards Sustainable Curriculum Greening." This mixed-method study assessed how environmental education (EE) was incorporated into teacher education programs (TEPs) in Region III, Philippines. Data were collected through validated questionnaires from 10 deans, 10 chairpersons, 171 teachers, and 344 students for the sample. Findings revealed that EE is integrated into several required courses, including physical education (PE), the new teacher education curriculum (NTEC) through the National Service Training Program (NSTP), and the Technology Science, and Society (STS) course within the general education curriculum. Additionally, environmental education is reflected in program outcomes and performance indicators. Additionally, teachers used environmental education in their classrooms and community outreach by conducting webinars and seminars that promoted environmental awareness, especially on social media. The environmental education integration received financial, administrative, and material support from the institution. While students demonstrated positive attitudes toward caring for the environment, their application of knowledge and skills needed improvement. Statistically significant correlations were found between students' knowledge and attitudes ($r = .593$, $p < .05$) and skill acquisition and attitudes ($r = .647$, $p < .05$). Teachers faced challenges such as limited environmental knowledge and insufficient time to guide students in environmental action. The study findings that while environmental education has been integrated into TEP, more emphasis is needed in vocational education courses to enhance knowledge and skill development. Eliavathi, et al. (2023) this research examines the effectiveness of teacher training programs in environmental education, with the aim of studying the major challenges and future strategies for improvement. It highlights the need to enhance teacher professionalism to support the achievement of the Sustainable Development Goals (SDGs). A triangulated approach was used including document analysis, surveys, and interviews.

A total of 65 teachers with experience in environmental education participated in the survey, and seven teachers were interviewed for further information. The findings point to the need to integrate sustainability dimensions environmental, economic, and socio-cultural in teacher training programs, as current training focuses primarily on the environmental aspect. The training aims primarily to impart environmental knowledge, but awareness building and promoting sustainable action are not emphasized. Therefore, future programs should prioritize not only knowledge but also actionable steps to promote awareness and sustainability. Full support from schools and other relevant stakeholders is crucial to successfully implement these training initiatives. Atorina, et al. (2024) in their article emphasizes the global importance of promoting environmental awareness in individuals. It explores scientific perspectives on the content, structure and types of ecological consciousness. This study aims to highlight ways to prepare prospective primary school teachers to develop environmental consciousness. This article examines two major perspectives on ecological consciousness: the first focuses on personal responsibility through the lens of the individual's ecological experiences, while the second considers it within the "society-nature" system. Outlines the necessary principles and components (technological, managerial and communication) that contribute to this development. A pilot study was conducted among higher education students to evaluate efforts to promote environmental awareness among future primary school teachers. The paper highlights the importance of developing an environmental culture in primary school students, as this period is crucial for shaping their identity as future citizens. The results confirm the importance of the research, emphasizing the need to incorporate environmental education in early education to promote ecological awareness and responsibility from an early age. Deborah, O., Dada, Chris, E., & Nigel, C. (2018). This study addresses the gap in understanding the environmental literacy of in-service educators in New Zealand schools and the impact of environmental education on their future teaching





practices. The aim was to explore in-service teachers' perceptions of their readiness to teach environmental education. This study assessed environmental literacy among preservice teachers who were taking a required environmental education course as part of a teaching bachelor's degree, and used a mixed-method approach with a pre-test and post-test design. While environmental literacy showed only modest improvements, participants' confidence in teaching environmental education increased significantly. The findings provide valuable insights for enhancing teacher education programmes and curriculum design to better prepare future teachers to promote environmental literacy in schools.

Research Question

1.How in-service teachers of Science and humanities background differ on awareness about environmental and sustainability with reference to their gender, locale, Subject, parents' education, parents' occupation and category?

Research Objectives

- 1.To compare the mean rank of environmental awareness and sustainability of pre-service teachers belonging to their gender, locale, Subject, and category.
- 2.To examine In-service teachers' understanding of environmental education and sustainability concepts.

Research Hypothesis

There is significant difference between the mean rank of environmental awareness and sustainability of in-service teachers belonging to their gender, locale, Subject and category.

Null Hypotheses:

1. There is no significant difference between the mean rank of environmental awareness and sustainability of in-service teachers belonging to their gender.
2. There is no significant difference between the mean rank of environmental awareness and sustainability of in-service teachers belonging to their locale.
3. There is no significant difference between the mean rank of environmental awareness and sustainability of in-service teachers belonging to their subject.
4. There is no significant difference between the mean rank of environmental awareness and sustainability of in-service teachers in their category.

MATERIALS AND METHODS

Research Design

To acquire a deeper knowledge of the research, the investigator employed a mixed methodology. To evaluate the in-service teachers' perception towards environmental awareness and sustainability, both quantitative and qualitative methods are employed.

Population

In-Service teachers from Science and Humanities backgrounds of higher education institutions of Lucknow district was the population of present study.

Sample Size: 115 in-service teachers' science and humanities background were the sample of the present study.

Sampling: The purposive sampling has been used by the researchers to select the participants from one central university, one state university and two degree colleges of rural areas.



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The researchers developed the Sustainability Scale (EASS) and Environmental Awareness (EA) for data collection. Also, to gain a deeper understanding of the topic, the researchers conducted unstructured interviews.

RESULT**Quantitative Data Analysis**

It is evident from Table No. 3 that the Mann-Whitney U-value is a substantial 1300.500. The data suggests that there are no notable differences in the mean ranks of Environmental Awareness scores between in-service gender teachers. The null hypothesis, according to which there is no discernible difference in the mean ranks of gender in-service teachers, is thus not rejected. As a result, it may be said that in-service gender teachers who were found to have environmental awareness in same extent. From Table No. 3, it can be seen that the Mann-Whitney U-value is 1448.500 which is not significant. It indicates that the mean ranks of sustainability of gender in-service teachers do not differ significantly. Thus, the null hypothesis that there is no significant difference in mean ranks of sustainability of gender in-service teachers is not rejected. It may, therefore, be said that both gender in-service teachers were found to have sustainability in same extent. It is evident from Table No. 6 that the Mann-Whitney U-value is a substantial 844.500. The data suggests that there are notable differences in the mean ranks of Environmental Awareness scores between in-service urban and rural teachers. The null hypothesis, according to which there is no discernible difference in the mean ranks of in-service teachers who are from locals areas, is thus rejected. As a result, it may be said that in-service teachers who were from locale areas had varying degrees of environmental awareness. From Table No. 3, it can be seen that the Mann-Whitney U-value is 973.000 which is significant. It indicates that the mean ranks Sustainability of urban and rural in-service teachers differ significantly. Thus, the null hypothesis that there is no significant difference in mean ranks of Sustainability of urban and rural in-service teachers is rejected. It may, therefore, be said that both urban and rural in-service teachers were found to have Sustainability in different extent. It is evident from Table No. 9 that the Mann-Whitney U-value is a substantial 1024.500. The data suggests that there are notable differences in the mean ranks of Environmental Awareness scores between in-service teachers who studied Agriculture as a subject and those in-service teachers who are from Non-Agriculture field. The null hypothesis, according to which there is no discernible difference in the mean ranks of in-service teachers who studied Agriculture subject and those are from Non-Agriculture subject, is thus rejected. As a result, it may be said that in-service teachers who were from Agriculture and Non-Agriculture subject had varying degrees of environmental awareness.

It is evident from Table No. 9 that the Mann-Whitney U-value is a substantial 1252.000. The data suggests that there are notable differences in the mean ranks of Sustainability scores between in-service teachers who studied Agriculture as a subject and those in-service teachers who are from Non-Agriculture field. The null hypothesis, according to which there is no discernible difference in the mean ranks of in-service teachers who studied Agriculture subject and those are from Non-Agriculture subject, is thus rejected. As a result, it may be said that in-service teachers who were from Agriculture and Non-Agriculture subject had varying degrees of Sustainability. From Table No. 12, it can be seen that the Mann-Whitney U-value is 1579.500 which is not significant. It indicates that the mean ranks Environmental Awareness of those in-service teachers who belong from reserved category and those who are from unreserved category do not differ significantly. Thus, the null hypothesis that there is no significant difference in mean ranks of Environmental Awareness of in-service teachers of reserved category and those from unreserved category is not rejected. It may, therefore, be said that those in-service teachers of reserved and unreserved category were found to have Environmental Awareness in same extent. From Table No. 18, it can be seen that the Mann-Whitney U-value is 1622.000 which is not significant. It indicates that the mean ranks Sustainability of in-service teachers of reserved and unreserved category do not differ significantly. Thus, the null hypothesis that there is no significant difference in mean ranks of Sustainability of in-service teachers of reserved category and unreserved category is not rejected. It may, therefore, be said that those in-service teachers of reserved category and unreserved category were found to have Sustainability in same extent.





Qualitative Data Analysis

To examine In-service teachers' understanding of environmental education and sustainability concepts

Understanding environmental sustainability and environmental education concepts is important for in-service teachers for effective transaction of learning of students they will teach. The responses them highlighted the strong awareness of environmental and sustainability concepts but their inability to teach effectively in the classroom. As one of the respondents said "I feel confident teaching about pollution and recycling, but when it comes to climate change or renewable energy, I struggle" which reflected the better understanding of traditional topics in comparison to mere complex topics. Another teacher said, "Sustainability feels like an add-on in the curriculum, and we don't have enough time or resources to teach it properly.". This showcased the frustration of the In-service teachers as it added to their work. This point highlighted the limited curriculum support and lack of resources. Despite all the challenges it is also found that In-services teachers are motivated and as one of the respondents said "It's important to educate students about sustainability because they are the ones who will face these global challenges in the future." The conclusion of the qualitative study indicates that in-service teachers have a firm grasp of sustainability and environmental education principles, particularly with regard to well-known subjects like recycling and pollution. However, they face challenges teaching more complex issues like climate change and renewable energy. Teachers expressed frustration over the lack of time, resources, and curriculum support, with some viewing sustainability as an "add-on" rather than an integral part of the curriculum. Despite these obstacles, teachers remain motivated, recognizing the importance of preparing students to address future global challenges. This reflects a willingness to integrate sustainability education, despite the need for better institutional support and resources.

DISCUSSION

Integrating environmental sustainability into higher education teaching practices is important to prepare students to face global challenges. While teachers show strong motivation and understanding, the researcher in his study tried to shed light on what different in-service teachers think about environmental sustainability awareness. Because both classes of teachers take a similar approach to environmental education, the researcher's study environmental sustainability awareness among teachers working in higher education institutions revealed that there was no difference in the views of men and women regarding this awareness on the basis of class. If we talk about rural and urban areas, it was found that people from rural areas, since they are closer to the environment, are more connected to their environment as a profession and are alert towards its protection, whereas people from urban areas, due to not being so connected to the environment, are not able to focus on environmental awareness as much as people from rural areas. Similarly, if we talk about the teaching subject, it was found that those who do teaching work in the field of agriculture, along with paying more attention to environmental awareness, also work to spread awareness through teaching and education while being aware of the environment. Whereas people from non-agriculture are aware about the environment but due to not working in this field, they are not able to focus on environmental awareness. If we look at the teachers or parents of students from the professional point of view, then this difference is seen that those whose parents are in government jobs, they are not able to pay attention to environmental awareness due to work arrangements, whereas on the contrary, if we talk about non-government professionals, then they are aware of the environment because their main work is personally affected by it. A vital part of the growth of the nation and society is played by teachers. Thus, the researcher, through his paper, studied various dimensions and emphasized that we need to train more in-service teachers of higher education institutions on environmental sustainability awareness so that they can be more conscious about the environment.

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Sangeeta Chauhan *et al.*,**Table.1: Ranks**

Ranks				
	Gender	N	Mean Rank	Sum of Ranks
Environmental Awareness	Male	74	55.07	4075.50
	Female	41	63.28	2594.50
	Total	115		
Sustainability	Male	74	58.93	4360.50
	Female	41	56.33	2309.50
	Total	115		

Table.2: Test Statistics

Test Statistics		
	Environmental Awareness	Sustainability
Mann-Whitney U	1300.500	1448.500
Wilcoxon W	4075.500	2309.500
Z	-1.271	-.401
Asymp. Sig. (2-tailed)	.204	.689
a. Grouping Variable: Gender		

Table.3: Gender-wise Mean Ranks, N and Mann-Whitney U--values of Environmental Awareness and Sustainability of in-service teachers

Variable	Gender	Mean Ranks	N	Mann-Whitney U-values	Remark
Environmental Awareness	Male	55.07	74	1300.500	P<0.05
	Female	63.28	41		
Sustainability	Male	58.93	74	1448.500	P<0.05
	Female	56.33	41		

Table.4: Ranks

Ranks				
	Locale	N	Mean Rank	Sum of Ranks
Environmental Awareness	Urban	80	51.06	4084.50
	Rural	35	73.87	2585.50
	Total	115		
Sustainability	Urban	80	63.34	5067.00
	Rural	35	45.80	1603.00
	Total	115		

Table.5: Test Statistics

Test Statistics		
	Environmental Awareness	Sustainability
Mann-Whitney U	844.500	973.000
Wilcoxon W	4084.500	1603.000
Z	-3.394	-2.599
Asymp. Sig. (2-tailed)	.001	.009
a. Grouping Variable: Locale		





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Table.6: Locale -wise Mean Ranks, N and Mann-Whitney U--values of Environmental Awareness and Sustainability of In-Service Teachers

Variable	Locale	Mean Ranks	N	Mann-Whitney U-values	Remark
Environmental Awareness	Urban	51.06	80	844.500	p>0.05
	Rural	73.87	35		
Sustainability	Urban	63.34	80	973.000	p>0.05
	Rural	45.80	35		

Table.7: Ranks

Ranks				
	Subject	N	Mean Rank	Sum of Ranks
Environmental Awareness	Agriculture	64	67.49	4319.50
	Non-Agriculture	51	46.09	2350.50
	Total	115		
Sustainability	Agriculture	64	63.94	4092.00
	Non-Agriculture	51	50.55	2578.00
	Total	115		

Table.8: Test Statistics

Test Statistics		
	Environmental Awareness	Sustainability
Mann-Whitney U	1024.500	1252.000
Wilcoxon W	2350.500	2578.000
Z	-3.438	-2.142
Asymp. Sig. (2-tailed)	.001	.032
a. Grouping Variable: Pedagogy		

Table.9: Subject-wise Mean Ranks, N and Mann-Whitney U--values of Environmental Awareness and Sustainability of In-Service Teachers

Variable	Subject	Mean Ranks	N	Mann-Whitney U-values	Remark
Environmental Awareness	Agriculture	67.49	64	1024.500	p>0.05
	Non-Agriculture	46.09	51		
Sustainability	Agriculture	63.94	64	1252.000	p>0.05
	Non-Agriculture	50.55	51		

Table.10: Ranks

Ranks				
	Category	N	Mean Rank	Sum of Ranks
Environmental Awareness	Reserved	55	59.28	3260.50
	Unreserved	60	56.83	3409.50
	Total	115		
Sustainability	Reserved	55	57.49	3162.00
	Unreserved	60	58.47	3508.00
	Total	115		





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Table.11: Test Statistics

Test Statistics		
	Environmental Awareness	Sustainability
Mann-Whitney U	1579.500	1622.000
Wilcoxon W	3409.500	3162.000
Z	-.397	-.157
Asymp. Sig. (2-tailed)	.692	.875
a. Grouping Variable: Category		

Table.12: Category-wise Mean Ranks, N and Mann-Whitney U--values of Environmental Awareness and Sustainability of In-Service Teachers

Variable	Category	Mean Ranks	N	Mann-Whitney U-values	Remark
Environmental Awareness	Reserved	59.28	55	1579.500	P<0.05
	Unreserved	56.83	60		
Sustainability	Reserved	57.49	55	1622.000	P<0.05
	Unreserved	58.47	60		





An Observational Analysis of *Snayu*: A Focus on *Shakhagata Pratanvati Snayu* w.s.r. to Upper limb

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ABSTRACT

The anatomical concepts of Ayurveda, particularly those provided by ancient Acharyas, must be properly interpreted using modern instruments such as cadaveric dissection. Among these terms, *Snayu* is particularly important. However, there is a disagreement between Ayurvedic and modern research over the classification, enumeration, and structural understanding of *Snayu*. Acharya Sushruta categorizes *Snayu* into four types—*Pratanavati*, *Vrutta*, *Sushira*, and *Pruthula*—with a total of 900. 600 *Snayu* are concentrated in the *Shakha* (limbs) and *Sandhi* (joints). *Pratanavati Snayu* are found specifically in *Shakha* and *Sandhi*, whereas *Vrutta Snayu* are frequently compared to *Kandara* (ligaments or tendons). *Sushira Snayu* are found at the distal extremities of the stomach, colon, and bladder, whereas *Pruthula Snayu* are found in cage-like structures such as the thoracic cage and cranium. Despite these descriptions, modern science has yet to provide a definitive structural analysis of *Snayu*, resulting in ambiguity in interpretation. This study seeks to close the gap by focusing on the *Pratanavati Snayu*. The number and structure of *Pratanavati Snayu* were studied and analyzed using an observational approach. This study aims to improve understanding of *Pratanavati Snayu* by using current dissection techniques and comparing the results to old Ayurvedic writings. The study advances the subject of Ayurvedic anatomy by offering a more exact interpretation of *Snayu*, creating the groundwork for future research that will integrate traditional knowledge with modern anatomical science.

Keywords: *Snayu*, *Pratanavati Snayu*, Ligament, Tendon, Aponeurosis.





INTRODUCTION

Snayu means literally to bind or to hold[1]. Ayurvedic Classic *Snayu* is defined as something that links the joints and allows the body to support its own weight, much like a fibrous structure[2]. It is said that *Snayu* originated from *Kharapaka* of *Sneha* of *Medas*[3]. According to Acharya Sarangadhara, *Snayu* is a structure that connects the body's *Mamsa*, *Asthi*, and *Medas*[4]. *Snayu* is regarded by Dr. D G Thatte as a muscle fiber[5]. Moreover, *Upadhatu* of *Medas*[6] and *Snayu* of *Medas* are thought to be the essence of each[7]. It is stated that *Mastulunga*, who resides in *Mastiska*[8], is the Moolasthan of *Snayu*. Acharya Gananath Sen states that there are two kinds of *snayu*: i. *snayumahati* and ii. *snayuvyakthi*. *Snayumahati* is a bundle (*Snayuguchha*) that joins bones and provides support and strength to joints. *Snayuvyakthi* (visceral connective tissue) is identified as a structure linked to *Kandara*, *Amasaya*, and *Pakwasaya*[9]. Acharya Susruta categorized the 900 *Snayu* into four types: *Pratanavati*, *Vrutta*, *Sushira*, and *Pruthula*. *Pratanavati Snayu* is prevalent across *Shakha* and *Sandhi*. Experts identify *Vrutta Snayu* as *Kandara*. *Sushira Snayu* can be located at the distal ends of *Amasaya*, *Pakwasaya*, and *Basti*. *Pruthula Snayu* can be found in cage-like structures of the body, such as the thoracic cage and cranium. Of the 900 *Snayu*, 600 are in *Shakha* and *Sandhi* [10].

Snayu Regional and Numerical Classification

Aims and Objectives

Aim

To comprehend and validate the concept of *Snayu*, namely *Shakhagata Pratanavati Snayu*(Upper limb), through an observational study.

Objectives

To carry out an observational study on *Pratanvati Snayu* in *Shakhas*(Upper limb), specifically on *Snayu Sharir*.

To confirm the exact meaning of *Snayu* based on existing considerations.

MATERIALS AND METHODS

Materials Required

- 5 cadavers taken from Rachana Sharir Department of Parul Institute of Ayurveda.
- Dissection table
- Instruments
- Gloves
- Camera.

Sources of Data

- Literary Study & Conceptual study was done by the data compiled from-
 - 1.A comprehensive collection of Ayurvedic Samhitas and other ancient and contemporary literature.
 - 2.Textbooks on allied medical science and anatomy.
 - 3.Sources include journals, research papers, and articles from various periodicals and newspapers.
 - 4.Access subject-related information on the internet.

- The theoretical portion will rely on observation, compilation, and analysis of the data gathered from the aforementioned sources. The Parul Institute of Ayurveda in Vadodara, Gujarat's Department of Rachana Sharir conducted a study on cadaver dissection of the entire body.

Observation Study

- Five Cadavers were used in the study.
- The dissection of 05 Cadavers was done in accordance with "Cunningham's Manual of Dissection" in this region.
- The dissection process was carried out layer by layer, closely monitored, and carefully examined.





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• Method of Collection of Data

- Five Cadavers were dissected in accordance with "Cunningham's manual of dissection," and observations were made.
- It was determined that *Pratanavati Snayu* (Upper limb) was based on structure and function.
- Sample size: 05 male Cadavers

Observations

- The dissection of 05 Cadavers (male) using "Cunningham's dissection manual" yielded important anatomical findings. Following incision, the following structures were observed:
- Under The Skin:
 1. The superficial fatty layer is made up of adipose tissue and resides just beneath the skin. It helps to insulate and store energy.
 2. Deep fascia is a dense, fibrous layer that surrounds muscles, nerves, and blood vessels, providing structural support.
- Ayurvedic writings define the *Pratanavati Snayu* (branched or fibrous ligaments/tendons) as being located in the extremities. Similar structures were discovered during the dissection, particularly in the upper limb. These features match to the fibrous tissues mentioned in the classics, proving the presence of branched or spreading fibrous structures similar to *Snayu's* description in Ayurvedic medicine.

Observation on Arm Observation on Forearm And Hand Observation on Wrist And Hand Observation on Back Of Forearm And Hand

DISCUSSION

In *Dhanurveda*, the term "*Snayu*" refers to strong, cord-like formations resembling bowstrings due to their strength. In Ayurveda, *Snayu* are ligaments made up of fine fibers that tie body parts together. As Acharya Sushruta points out, these fibers can also be employed for suturing in surgery. *Snayu* serve an important role in connecting joints, similar to how cords tie together wooden planks in a boat. *Snayu* is defined by Acharya Gananath Sen as thick fibers that bind joints (*Sandhi*), acting as both a binding agent for bones and joints (*Asthi* and *Sandhi*) and a source of structural strength. A cadaveric dissection of the upper limb was conducted in the Department of Rachana Sharir at Parul Institute of Ayurveda, following the guidelines of Cunningham's Manual of Dissection. In line with Acharya Sushruta's description, the *Pratanavati Snayu*, a specific type of ligament, was identified in all four limbs (*Sakhas*). This upper limb dissection was performed on one cadaver, allowing for detailed study of the anatomical features of *Snayu* in accordance with classical Ayurvedic knowledge.

Discussion On Upper Limb Muscles

SR NO.	Muscles	Structure considered as <i>Pratanavati snayu</i>
1	Muscles of Arm	Coracobrachialis
2		Biceps brachii
3		Brachialis
4		Triceps brachii
5	Superficial muscles of Forearm	Pronator teres
6		Flexor carpi radialis
7		Palmaris longus
8		Flexor digitorum superficialis
9		Flexor carpi ulnaris
10	Deep muscles of Forearm	Flexor digitorum profundus
11		Flexor pollicis longus
12		Pronator quadratus





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13	Muscles of	Abductor pollicis brevis	1 tendon of abductor pollicis brevis
14	Thenar	Flexor pollicis brevis	1 tendon of Flexor pollicis brevis
15	eminence	Opponens pollicis	1 tendon of abductor pollicis brevis
16	Muscles of	Abductor digiti minimi	1 tendon of abductor digiti minimi
17	Hypothenar	Flexor digiti minimi	1 tendon of flexor digiti minimi
18	eminence		
18	Muscles of	Adductor pollicis	1 tendon of adductor pollicis
19	Hand	Palmaris brevis	1 tendon of palmaris brevis
20		4 Lumbricals	brevis4 tendons of lumbricals
21		Palmar interossei	4 tendons of palmar interossei
22		Dorsal interossei	4 tendons of dorsal interossei
23	Muscles of	Brachioradialis	1 tendon of brachioradialis
24	Back of	Extensor carpi radialis longus	1 tendon of Extensor carpi radialis longus
25	Forearm and	Extensor carpi radialis brevis	1 tendon of Extensor carpi radialis brevis
26	hand	Extensor digitorum	4 tendon of Extensor digitorum
27		Extensor digiti minimi	1 tendon of Extensor digiti minimi
28		Extensor carpi ulnaris	1 tendon of Extensor carpi ulnaris
29		Anconeus	1 tendon of Anconeus
30	Deep muscles	Supinator	1 tendon of Supinator
31	of Back of	Abductor pollicis longus	1 tendon of Abductor pollicis longus
32	Forearm	Extensor pollicis brevis	1 tendon of extensor pollicis brevis
33		Extensor pollicis longus	1 tendon of extensor pollicis longus
34		Extensor indicis	1 tendon of extensor indicis

CONCLUSION

Following a thorough examination, analysis, and review of the literature, the following conclusions can be made: A vast array of fibrous structures found in the limbs, including as ligaments, tendons, aponeuroses, retinacula, and fascia, are included in *Pratanavati Snayu*. These structures are similar to *Snayu* in terms of structure, function, or pathology. Comprehensive View: Acharya Sushruta's description of the *Pratanavati Snayu* is more accurately represented when all fibrous structures in the limbs are taken into account, even though solely focusing on ligaments or tendons may not account for all *Snayu*. From an Ayurvedic perspective, Acharya Sushruta compared the role of *Snayu* to the ropes that bind a boat, providing support and stability for the joints in the body. *Snayu* are strong, thread like structures that are essential for binding and preserving the structural integrity of limbs and joints in the body.

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Table.1: Classification of snayu

Sr. No	Region	Enumeration
1	Shakha(Extrimities)	600
2	Koshta(Trubk)	230
3	Greeva(Neck) And Above	70
4	Total	900



Biceps Brachii



Triceps Brachii

Figure.1: Muscles And Tendons of Arm



Prometer Teres



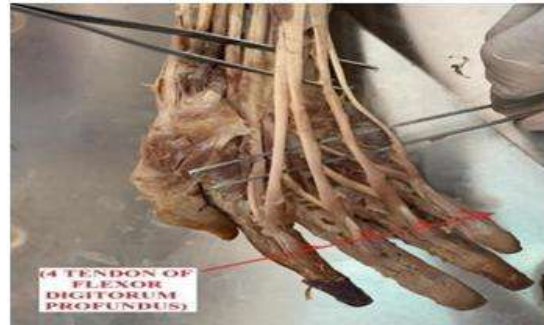
Palmaris Longus

Figure.2: Superficial Muscles of Forearm And Hand





Flexor Digitorum Profundus



4 Tendon

Figure.3: Deep muscles of forearm and hand



Flexor Retinaculum



Extensor Retinaculum

Figure.4:Flexor And Extensor Retinaculum



Abductor Pollicis Bravis

Figure.5:Figures of Thenar Eminence



Adductor Pollicis

Figure.6:Adductor of Thumb





Dorsal Interossei



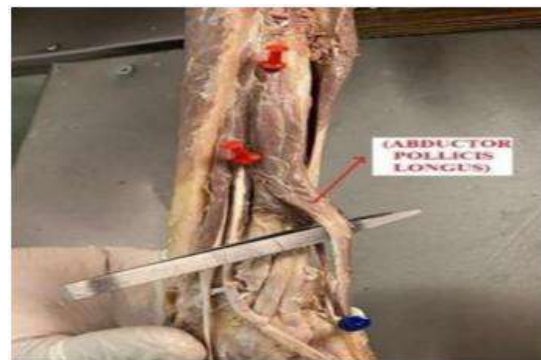
Palmar Interossei

Figure.7: Palmar And Dorsal Interossei



Extensor Carpi Radialis Longus

Figure.8: Superficial Muscles of Back of Forearm



Abductor Pollicis Longus

Figure.9: Deep Muscles of Back of Forearm





Minus Ordering in Ternary Semiring

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ABSTRACT

We investigate the concept of Minus ordering in Ternary Semiring. We derive some equivalent conditions for minus ordering by using generalized inverses.

Keywords: regular, ordering, g- inverses, Ternary semiring

2020 mathematical science classification : 16Y60, 16U90

INTRODUCTION

In 1932, Lehmer [1] explored ternary algebraic system theory. He studied “triplexes”, which are ternary algebraic systems that finally turn out to be ternary groups. A generalization of ternary rings are called ternary semirings, as presented by Dutta et al [2]. Ternary semiring is a superset of semiring. Negative integers forms a ternary semiring but it does not form a semiring. In 1920, E.H. Moore established the concept of the generalized inverse of a matrix, defining the unique generalized inverse through the use of matrices projectors. Penrose demonstrated in 1955 that Moore’s inverse is the unique matrix that can satisfy four equations. [3]. The notion of regular element was first introduced by Von Neumann in 1936 [4]. Meenakshi AR et al [6] explicate the minus ordering for fuzzy matrices and established that he minus ordering is a partial ordering in the set of all regular matrices. Meenakshi [7] has characterized the minus ordering on matrices in terms of their generalized inverses. In this paper we studied the concept of minus ordering for an elements in ternary semiring as a generalization of the minus ordering for regular fuzzy matices.





PRELIMINARIES

In this work, T represents the Ternary semiring; it is abbreviated as T.S.R. throughout this paper.

Definition 2.1. The term "ternary semiring" refers to $T \neq \Phi$, a binary addition, and a ternary multiplication called juxtaposition if $(T, +)$ is a semigroup that commutes that fulfilling the requirements listed below:

- (i) $(abc)de = a(bcd)e = ab(cde)$,
- (ii) $(a + b)cd = acd + bcd$,
- (iii) $a(b + c)d = abd + acd$,
- (iv) $ab(c + d) = abc + abd$, for all a, b, c, d, e in T .

Remark: \mathbb{Z}^- is a natural example of a ternary semiring, which has ternary multiplication and regular addition.

Definition 2.2. If an element a exists in T such that $ababa = a$, then a is considered regular. The element b is represented as a^- and is also known as the generalized inverse or 1-inverse of the element ' a ' and the set of all 1-inverses is denoted by $a\{1\}$. If every element in a T.S.R is regular, then we say T.S.R is regular.

Definition 2.3. If there is an element a in $T \exists babab = b$, then a is considered anti-regular. The name for element b is 2-inverse of a and set of all 2-inverses of a is denoted by $a\{2\}$. The both conditions in Definition (2.2) and Definition (2.3) satisfied by a single element b is called 1-2 inverse and is denoted by \hat{a} . In Definition (2.2), if the ' b ' is unit then ' a ' is called unit regular.

Definition 2.4. An element $a \in T$ has Moore penrose inverse if there exists an $b \in T$ such that the following equations hold:

$$(1) ababa = a \quad (2) babab = b \quad (3) (abe)^T = abe \quad (4) (eba)^T = eba.$$

Where e is identity element, here b is unique and denoted by a^+

In Definition (2.4), the element b is satisfy the equations (1) and (3), then we say that element is {1,3}-inverse of ' a ' and b satisfy the equation (1) and (4) then we say that b is {1,4}-inverse of ' a '.

The transpose of a is written as a^T and the following properties of the transpose will be used:

$$\begin{aligned} a^{TT} &= a, \\ (a + b)^T &= a^T + b^T, \\ (abc)^T &= c^T b^T a^T. \end{aligned}$$

Minus ordering in ternary semiring

Definition 3.1. For $a \in T_{Reg}$ and $b \in T$ the minus ordering denoted as \preceq is defined as by $a \preceq b$ iff $aa^-a = aa^-b = ba^-a$; $a^-aa = a^-ba = a^-ab$; $aaa^- = baa^- = aba^-$ for some $a^- \in a\{1\}$.

Throughout this paper T_{Reg} denote regular ternary semiring.

Example 1. Let $T_{Reg} = \{0, 1, 2, 3, 4\}$ be a ternary semiring with respect to modulo addition and modulo multiplication, the minus ordering defined as follows:

Let $a = 3$; $a^- = 2$; $b = 3$ satisfy $aa^-a = aa^-b = ba^-a$; $a^-aa = a^-ba = a^-ab$; $aaa^- = baa^- = aba^-$

+s	0	1	2	3	4
0	0	1	2	3	4
1	1	2	3	4	0
2	2	3	4	0	1
3	3	4	0	1	2
4	4	0	1	2	3

□s	0	1	2	3	4
0	0	0	0	0	0
1	0	1	2	3	4
2	0	2	4	1	3
3	0	3	1	4	2
4	0	4	3	2	1

In this section, we present some results on the minus ordering of the elements





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Theorem 3.1. For $a \in T_{Reg}, b \in T$ the following are equivalent:

- (i) $a \preceq b$
 (ii) $a = aa^-aa^-b = ba^-aa^-a = aa^-ba^-a$

Proof: (i) \Rightarrow (ii) since $a \preceq b \Leftrightarrow aa^-a = aa^-b = ba^-a$; $a^-aa = a^-ba = a^-ab$; $aaa^- = baa^- = aba^-$

$$a = aa^-aa^-a = (aa^-a)a^-a = aa^-ba^-a \quad \text{-----(3.1)}$$

$$a = aa^-(aa^-a) = aa^-aa^-b \quad \text{-----(3.2)}$$

$$a = aa^-aa^-a = (aa^-a)a^-a = ba^-aa^-a \quad \text{-----(3.3)}$$

From Equations (3.1), (3.2) and (3.3) we get

$$a = aa^-aa^-b = ba^-aa^-a = aa^-ba^-a$$

(ii) \Rightarrow (i) Let $m = a^-aa^-aa^-$

$$amama = a(a^-aa^-aa^-)a(a^-aa^-aa^-)a$$

$$= aa^-aa^-a = a$$

$$\Rightarrow m \in a\{1\}$$

$$ama = a(a^-aa^-aa^-)a = a(a^-aa^-aa^-)aa^-aa^-b$$

$$= aa^-aa^-aa^-b = amb$$

$$\therefore ama = amb$$

Similarly we get $maa = mba = mab$ and $aam = bam = abm$

Hence $a \preceq b$ with respect to $m \in a\{1\}$.

Corollary 3.1. For $a \in T_{Reg}, b \in T$ and $a \preceq b$ with a is idempotent then $a = baa^-ba^-ab$

Proof: $aaa = a(aa^-aa^-a)a = (aaa^-)aa^-aa^-a^3 = baa^-aa^-aa^-a = b(aa^-a)a^-aa^-$

$$a = baa^-b(a^-aa^-) = baa^-ba^-ab \quad \text{-----(3.4)}$$

Theorem 3.2. Let $a, b \in T_{Reg}$, If $a \preceq b$ then $b\{1\} \subseteq a\{1\}$.

Proof: Since $a \preceq b \Leftrightarrow a = aa^-aa^-b = ba^-aa^-a = aa^-ba^-a = baa^-ba^-ab$

Suppose $b^- \in b\{1\}$

$$ab^-ab^-a = aa^-aa^-b(b^-)baa^-ba^-ab(b^-)a$$

$$= aa^-aa^-b(b^-)b(aa^-aa^-a)a^-ba^-(aa^-aa^-a)b(b^-)a$$

$$= aa^-aa^-b(b^-)b(aa^-a)a^-aa^-ba^-aa^-(aa^-a)b(b^-)a$$

$$= aa^-aa^-b(b^-)b(ba^-a)a^-aa^-ba^-aa^-(aa^-b)b(b^-)a$$

$$= aa^-aa^-b(b^-)bbb^-ba^-bb(b^-)a$$

$$= aa^-aa^-b(b^-)bbb(b^-)a = aa^-aa^-b(b^-)b(b^-)a$$

$$= aa^-aa^-b(b^-)b(b^-)ba^-aa^-a = aa^-aa^-ba^-aa^-a$$

$$= aa^-aa^-a = a$$

$$\therefore ab^-ab^-a = a$$

Hence $ab^-ab^-a = a$ for each $b^- \in b\{1\}$

$$\therefore b\{1\} \subseteq a\{1\}$$

Corollary 3.2. If $a \preceq b$ with b idempotent element then $b \in a\{1\}$.

Proof: Since b is idempotent, b is regular and b is a 1-inverse of ' b '. $\therefore b \in b\{1\}$, By Theorem 3.2, $b\{1\} \subseteq a\{1\}$.

Hence we get $b \in a\{1\}$.

Theorem 3.3. If $a, b \in T_{Reg}$, then the following subsequent are equivalent

- (i) $a \preceq b$
 (ii) $a = ab^-bb^-b = bb^-bb^-a = ab^-bb^-a = bab^-bb^-ab$ for all $b^- \in b\{1\}$

Proof: By Theorem (3.1), $a = aa^-aa^-b = aa^-aa^-ba^-aa^-b$





$$\begin{aligned}
 &= aa^{-}aa^{-}(bb^{-}bb^{-}b)a^{-}aa^{-}b \\
 &= ab^{-}bb^{-}ba^{-}aa^{-}b \quad (\because a = aa^{-}aa^{-}b) \\
 &= ab^{-}bb^{-}ba^{-}aa^{-}aa^{-}aa^{-}b \quad (\because a = a^{-}aa^{-}aa^{-}) \\
 &= ab^{-}bb^{-}ba^{-}aa^{-}a = ab^{-}bb^{-}a \quad (\because a = ba^{-}aa^{-}a) \\
 \therefore a &= ab^{-}bb^{-}a \quad \text{-----(3.5)}
 \end{aligned}$$

By Theorem 3.1, $a = ba^{-}aa^{-}a$

$$= (bb^{-}bb^{-}b)a^{-}aa^{-}a = bb^{-}bb^{-}a \quad \text{-----(3.6)}$$

Again from Theorem (3.1) and similar manner of Equation (3.6) we obtain

$$a = ab^{-}bb^{-}b \quad \text{-----(3.7)}$$

$$a = baa^{-}ba^{-}ab = ba(a^{-}aa^{-}aa^{-})ba^{-}ab = baa^{-}aa^{-}ab$$

$$= bab = bab^{-}bb^{-}ab \quad (\text{By using Equation (3.5)}) \quad \text{-----(3.8)}$$

From Equations (3.5, 3.6, 3.7 and 3.8) we get

$$a = ab^{-}bb^{-}b = bb^{-}bb^{-}a = ab^{-}bb^{-}a = bab^{-}bb^{-}ab$$

$$(ii) \Rightarrow (i) \text{ Let } h = b^{-}ab^{-}ab^{-} \Rightarrow aha = a(b^{-}ab^{-}ab^{-})a = a(b^{-}ab^{-}ab^{-})a$$

$$= ab^{-}ab^{-}a = a \quad (\because a = ab^{-}ab^{-}a)$$

$$\Rightarrow h \in a\{1\}$$

$$\text{Since } a = ab^{-}bb^{-}b \Rightarrow aha = a(b^{-}ab^{-}ab^{-})a = ab^{-}ab^{-}ab^{-}(ab^{-}bb^{-}b) = ab^{-}ab^{-}bb^{-}b = ab^{-}ab^{-}bb^{-}ab^{-}bb^{-}b$$

$$= ab^{-}ab^{-}bb^{-}b \quad (\because a = ab^{-}bb^{-}a)$$

$$\therefore aha = ahb \quad \text{and} \quad aha = bha$$

$$\text{Similarly, we get } aah = bah = abh; haa = hab = hba$$

Hence $a \preceq b$ with respect to $h \in a\{1\}$.

Theorem 3.4. For $a \in T_{Reg}$, $b \in T$ with $a \preceq b$ the following holds:

$$(i) \quad \text{If } b = b^3, \text{ then } a = a^3$$

$$(ii) \quad \text{If } b = 0, \text{ then } a = 0$$

$$\begin{aligned}
 \text{Proof: (i)} \quad a^3 &= aaa = aa^{-}aa^{-}a \quad aa^{-}aa^{-}a \quad aa^{-}aa^{-}a \\
 &= aa^{-}aa^{-}(a \quad (aa^{-}a)a^{-}a \quad aa^{-})aa^{-}a \\
 &= aa^{-}aa^{-}(a \quad ba^{-}aa^{-}a \quad aa^{-})aa^{-}a \\
 &= aa^{-}aa^{-}(a \quad a \quad aa^{-})aa^{-}a \quad (\because a = ba^{-}aa^{-}a) \\
 &= aa^{-}(aa^{-}a)(a \quad aa^{-})aa^{-}a = aa^{-}(aa^{-}bbaa^{-})aa^{-}a \\
 &= aa^{-}aa^{-}bb(aa^{-}a)a^{-}a = aa^{-}aa^{-}bb(ba^{-}a)a^{-}a \\
 &= aa^{-}aa^{-}b^3a^{-}aa^{-}a \\
 &= aa^{-}aa^{-}baa^{-}aa^{-}a \quad \text{-----(3.9)} \\
 &= aa^{-}aa^{-}a = a
 \end{aligned}$$

$$\therefore a^3 = a$$

From Equation (3.9)

$$(ii) a^3 = aa^{-}aa^{-}ba^{-}aa^{-}a$$

$$= aa^{-}aa^{-}(0)a^{-}aa^{-}a = 0 \quad (\because b = 0)$$

$$\therefore a = 0$$

Corollary 3.3. If $a \preceq b$ then $b \in a^{-}\{1\}$

Proof: By Definition (2.5) We have $aa^{-}a = aa^{-}b = ba^{-}a$

$$a^{-}aa^{-}aa^{-} = a^{-}(aa^{-}a)a^{-} = a^{-}(aa^{-}b)a^{-}$$

$$= (a^{-}aa^{-}aa^{-})aa^{-}ba^{-} = a^{-}aa^{-}(aa^{-}b)a^{-}ba^{-}$$

$$= (a^{-}aa^{-}aa^{-})ba^{-}ba^{-} = a^{-}ba^{-}ba^{-} = a^{-}$$

$$\therefore b \in a^{-}\{1\}$$

Definition 3.2. For $a, b \in T_{Reg}$ and $b^{-} \in T$ the minus ordering denoted as \preceq^{-} is defined by $a^{-} \preceq^{-} b^{-}$ iff $a^{-}aa^{-} = b^{-}aa^{-} = a^{-}ab^{-}$; $a^{-}a^{-}a = a^{-}b^{-}a = b^{-}a^{-}a$; $aa^{-}a^{-} = aa^{-}b^{-} = ab^{-}a^{-}$ for some $a^{-} \in a\{1\}, b^{-} \in b\{1\}$.

Theorem 3.5. If $a, b \in T_{Reg}$ and a^{-}, b^{-} exists then the following are equivalent





- (i) $a^- \leq b^-$
 (ii) $a^- = a^-aa^-ab^- = b^-aa^-aa^- = a^-ab^-aa^- = b^-a^-ab^-aa^-b^-$

Proof: By Theorem (3.1)

$$a^- \leq b^- \Leftrightarrow a^-aa^- = a^-ab^- = b^-aa^-; aa^-a^- = aa^-b^- = ab^-a^-;$$

$$a^-a^-a = b^-a^-a = a^-b^-a$$

$$\text{Let } a^- = a^-aa^-aa^- = (a^-aa^-)aa^- = a^-ab^-aa^- \quad \text{-----(3.10)}$$

$$a^- = a^-aa^-aa^- = b^-aa^-aa^- \quad \text{-----(3.11)}$$

$$a^- = a^-aa^-aa^- = a^-aa^-ab^- \quad \text{-----(3.12)}$$

From Equations (3.10, 3.11 and 3.12) we get

$$\therefore a^- = a^-aa^-ab^- = b^-aa^-aa^- = a^-ab^-aa^- = b^-a^-ab^-aa^-b^-$$

$$(ii) \Rightarrow (i) \text{ Let } x = aa^-aa^-a$$

$$a^-xa^-xa^- = a^-(aa^-aa^-a)a^-(aa^-aa^-a) = a^-aa^-aa^- = a^-x \in a^-\{1\}.$$

$$a^-xa^- = a^-(aa^-aa^-a)a^-aa^-ab^- = a^-aa^-aa^-ab^- = a^-xb^-$$

$$\therefore a^-xa^- = a^-xb^-$$

Similarly we get $xa^-a^- = xa^-b^- = xb^-a^-$ and $a^-a^-x = a^-b^-x = b^-a^-x$

Hence $a^- \leq b^-$ with respect to $x \in a^-\{1\}$

Corollary 3.4. If $a, b \in T_{Reg}$ and $a^- \leq b^-$ with a^- is idempotent then $a^- = b^-a^-aa^-aa^-b^-$

$$\text{Proof: } a^- = a^-a^-a^- = a^-a^-aa^-aa^-a^-$$

$$= (a^-a^-a)a^-aa^-a^- = b^-a^-aa^-(aa^-a^-)$$

$$a^- = b^-a^-aa^-aa^-b^- \quad \text{-----(3.13)}$$

Corollary 3.5. For $a, b \in T_{Reg}$, $a^- \leq b^-$ with respect to $a \Leftrightarrow a^- \leq b^-$ with respect to a^-

Theorem 3.6. For $a, b \in T_{Reg}$, then the following hold

- (i) $a^- \leq a^-$
 (ii) $a^- \leq b^-$ and $b^- \leq a^-$ then $a = b$
 (iii) $a^- \leq b^-$ and $b^- \leq c^-$ then $a^- \leq c^-$

Proof: (i) $a^- \leq a^-$ is obvious.

$$(ii) a^- \leq b^- \Leftrightarrow a = aa^-aa^-b = ba^-aa^-a = aa^-ba^-a = baa^-ba^-ab$$

$$b^- \leq a^- \Leftrightarrow b = bb^-bb^-a = ab^-bb^-b = bb^-ab^-b = abb^-ab^-baa = baa^-ba^-ab = (bb^-bb^-a)aa^-ba^-a(ab^-bb^-b)$$

$$= bb^-bb^-(ba^-aa^-a)aa^-ba^-a(aa^-aa^-b)b^-bb^-b$$

$$= bb^-bb^-ba^-aa^-a^3a^-aa^-bb^-bb^-b = bb^-bb^-ba^-aa^-aa^-aa^-bb^-bb^-b$$

$$= bb^-bb^-ba^-aa^-ab^-bb^-b (\because a = aa^-aa^-b)$$

$$= bb^-bb^-ba^-aa^-ab^-(bb^-ab^-b)b^-b (\because b = bb^-ab^-b)$$

$$= (bb^-bb^-)ab^-bb^-ba^-(b^-bb^-b) = (bb^-bb^-a)b^-bb^-(ab^-bb^-b)$$

$$= bb^-bb^-b = b$$

$$\therefore a = b$$

(iii) By Theorem (3.3),

$$a^- \leq b^- \Leftrightarrow a = ab^-bb^-b = bb^-bb^-a = ab^-bb^-a = bab^-bb^-ab$$

$$\text{By using Theorem (3.1) } b^- \leq c^- \Leftrightarrow b = bb^-bb^-c = cb^-bb^-b = bb^-cb^-b$$

$$\text{Let } u = b^-ab^-ab^- \text{ for } b^- \in b\{1\}$$

$$aua = a(b^-ab^-ab^-)a(b^-ab^-ab^-)a$$

$$= ab^-ab^-a = a$$

$$\therefore u \in a\{1\}$$

$$a = (bb^-bb^-a)u = (cb^-bb^-b)b^-bb^-a$$

$$= cb^-bb^-a = c(b^-ab^-ab^-)bb^-a$$

$$= cb^-ab^-a = cb^-ab^-a(b^-ab^-ab^-)a$$





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$$= cb^-ab^-ab^-a = cua$$

$$\therefore aua = cua = auc$$

Similarly we get $aa u = acu = cau$ and $uaa = uac = uca$

$$\therefore a \preceq c.$$

Hence the minus ordering is a partial ordering in T_{Reg} .

Theorem 3.7. For $a \in T_{Reg}$ and $b \in T$ we have the following hold $a \preceq b \Leftrightarrow a^T \preceq b^T$

Proof: Since $a \preceq b \Leftrightarrow aa^-a = aa^-b = ba^-a$; $a^-aa = a^-ba = a^-ab$;

$$aaa^- = baa^- = aba^-$$

$$aa^-a = aa^-b = ba^-a \Leftrightarrow (aa^-a)^T = (aa^-b)^T = (ba^-a)^T$$

$$\Leftrightarrow a^T a^{-T} a^T = b^T a^{-T} a^T = a^T a^{-T} b^T$$

$$\Leftrightarrow a^T a^T a^T = b^T a^T a^T = a^T a^T b^T$$

$$\therefore aa^-a = aa^-b = ba^-a \Leftrightarrow a^T a^T a^T = b^T a^T a^T = a^T a^T b^T$$

$$\text{Similarly we obtain } a^-aa = a^-ba = a^-ab \Leftrightarrow a^T a^T a^T = a^T b^T a^T = b^T a^T a^T$$

$$\text{and } aaa^- = baa^- = aba^- \Leftrightarrow a^T a^T a^T = a^T a^T b^T = a^T b^T a^T$$

$$\text{Hence } a \preceq b \Leftrightarrow a^T \preceq b^T.$$

Theorem 3.8. Let $a, b \in T_{Reg}$. If $a \preceq b$ then $(a + b)$ is regular and $(a^- + b^-)$ is a 1-inverse of $(a + b)$

Proof: By Theorem (3.1) and Theorem (3.3), we have

$$(a + b)(a^- + b^-)(a + b)(a^- + b^-)(a + b) = (a + b)$$

Hence $(a^- + b^-) \in (a + b)\{1\}$ and $(a + b)$ is regular.

Theorem 3.9. For $a, b \in T_{Reg}$, both b and c are minus ordering to each other and $c \in a\{2\}$ then $b \in a\{2\}$.

Proof: By Theorem(3.1), $b \preceq c \Leftrightarrow b = bb^-bb^-c = cb^-bb^-b = bb^-cb^-b$ ----- (I)

By Theorem 3.3, $b \preceq c \Leftrightarrow b = bc^-cc^-c = cc^-cc^-b = bc^-cc^-b$ ----- (II)

$$c \preceq b \Leftrightarrow c = cc^-cc^-b = bcc^-cc^- = cc^-bc^-c$$
----- (III)

$$c \preceq b \Leftrightarrow c = bb^-bb^-c = cb^-bb^-b = cb^-bb^-c$$
----- (IV)

Now $babab = (bc^-cc^-c)aba(cc^-cc^-b)$ (using Equation (II))

$$= (bc^-cc^-c)a(bb^-bb^-c)a(cc^-cc^-b) \text{ (using Equation (I))}$$

$$= (bc^-cc^-c)abb^-bb^-c(cc^-cc^-c)a(cc^-cc^-b) \text{ (using Equation (III))}$$

$$= bc^-cc^-cabb^-bb^-bc^-c(cc^-cc^-c)ca(cc^-cc^-b)$$

$$= bc^-cc^-cabb^-bb^-c(cc^-cc^-c)cc^-ca(cc^-cc^-b)$$

$$= bc^-cc^-cabb^-bb^-cc^-cc^-ca(cc^-cc^-b) \text{ (using Equation (III))}$$

$$= bc^-cc^-ca(bb^-bb^-c)cc^-ca(cc^-cc^-b)$$

$$= bc^-cc^-cacc^-cc^-ca(cc^-cc^-b) \text{ (using Equation (IV))} = bc^-cc^-caca(cc^-cc^-b) = bc^-cc^-cc^-cc^-b$$

$$= bc^-cc^-b = b \therefore b \in a\{2\}$$

Corollary 3.6. Let $a \in T$. The following statements are equivalent:

- (i) a^+ exists.
- (ii) a^T is a g-inverse of a

Proof: (i) \Leftrightarrow (ii) directly follows from the fact that a^T satisfy the defining equations of the Moore penrose inverse .

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Total Graph and Total Burning

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ABSTRACT

In order to find a total source vertex number $b_t(G)$, let us consider that G is a connected and an undirected simple graph. In this paper, we are discussing about total source vertex number $b_t(G)$ as well as total graph source vertex number $Tb(G)$. Specifically, we are finding a source vertex number of a Path P_n , a Cycle C_n , a Star $S_{1,k}$, a Petersen and a Wheel W_n . Secondly, To find a total graph source vertex number, let us consider G is a connected and an undirected graph, of course as we all know $T(G)$ is a planar graph. Here we are imposing the concept of burning number on a total graph. Before finding a source vertex number, we have to convert a graph into a total graph. Here we have taken a Star graph $S_{1,k}$. Burning is a discrete step by step process, the main intention of burning is to acquire a burning number within the limited period of time which is the so called source of the vertex and We know that a burning number is denoted as $b(G)$. In a total graph $T(G)$ of a graph G , whose vertex is adjacent to the edges and vertices and edges are incident in G . Total graph burning number denoted by $Tb(G)$.

Keywords: Burning number, Total Graph and Total burning.

INTRODUCTION

Over the last decade a few researchers have been working on burning. The 'burning Number' concept was introduced by Anthony Bonato in the year of 2014[1]. To burn a graph we require a minimum number of vertices, which is called as a Burning Number $b(G)$ or Source vertex number. Burning a graph is a precise procedure, let us fix the fire on any of one of the vertex which is identified as the source vertex. In the next step, we have to select a source

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vertex among the leftover vertices from round one, then the adjacent of the previously selected source vertex will begin to burn automatically which is said to be the basic step for attaining a graph. This process will be repeated till all the vertices burn subsequently. And our aim is to burn a graph to get a minimum source of vertices by burning all the vertices of a graph within the limited period of time. There are wide applications on burning number. It is most applied in the field of Social media, Networks and the contagion diseases ...e.t.c.,. Total graph was introduced by T. F Anderson and Badawi, and the total graph is denoted by $T(G)$, Let G be a graph with vertex set $V(G)$ and edge set $E(G)$.

2. Definitions

2.1. Burning

Burning is a discrete time step by step process, the main intention of burning is to acquire a burning number which is so called source of the vertex, within the limited period of time. The burning number is denoted by $b(G)[5]$.

2.2. Total burning

For any graph G , total burning amounts to be burning $T(G)$. Thus, vertices or edges may be burned in G , with fires spreading across edges. We define the total burning number of G as $b_t(G) = b(T(G))$; that is, the minimum number of rounds necessary for all elements of G to burn[2].

2.3.Total graph

The total graph $T(G)$ has point set $V(G) \cup X(G)$, and two points of $T(G)$ are adjacent whenever they are neighbors in $G[3]$.

3. Path graph

Path graph P_n is a connected graph as well as a tree.

3.1. Theorem: For a Path graph P_n the total burning number $b_t(P_n)$ is $\lceil \sqrt{n} \rceil$, only if $n \geq 2$.

Proof: As we know the path graph P_n burning number is $\lceil \sqrt{n} \rceil$. The total source vertex number of a path $b_t(P_n)$ is \sqrt{n} , when $n \geq 4$. And n should be a perfect square, of course, it is same for the next to the perfect square. For others it is, $\lceil \sqrt{n} \rceil$. Well we identified, $b_t(P_n) \geq b(P_n)$.

3.2. Theorem: For a Cycle graph C_n is a total burning $b_t(C_n)$, is $\lceil \sqrt{n} \rceil$, only when $n \geq 3$.

Proof: A Cycle graph is a total burning only if $n \geq 3$. A source vertex number for a cycle graph is $\lceil \sqrt{n} \rceil$. And here the total burning number is also a $\lceil \sqrt{n} \rceil$.

$$\therefore b_t(C_n) = b(C_n)$$

3.3. Theorem: For a star $S_{1,k}$, the total source vertex number $b_t(S_{1,k})$ is 2 when $k > 1$.

Proof: $S_{1,k}$ is a star graph. Here the middle of the vertex is adjacent to the all other vertices. Hence star is a complete bipartite graph. Therefore, the total source vertex number of a star graph $b_t(S_{1,n})$ is 2 only when $k > 1$.

$$b_t(S_{1,k}) = b(S_{1,k}) = 2.$$

3.4. Theorem: The total burning number of a Petersen graph is 3.

Proof: Petersen graph is a regular and an undirected graph with ten vertices and 15 edges. Each vertex has degree 3. The source vertex number of a Petersen graph is 3 and the total source vertex number of a Petersen graph is also a 3.

4. Wheel graph: A wheel W_n is an another version of Cycle, the inner centre vertex connects to all other vertices of a cycle. To form a wheel graph at least 4 vertices are much needed.





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4.1. Theorem: The total source vertex of a wheel $b_t(w_n)$ is 3, where $n \geq 4$.

Proof: Precisely w_n is a wheel graph with the minimum number of four vertices. where, the inner vertex is adjacent to the external vertices of a cycle. wheel w_n source vertex number is 2 and the total source vertex number of $b_t(w_n)$ graph is 3, only when n is greater than or equal to 4.

5. Star graph

$S_{1,n}$ is a star and a complete bipartite graph[4].

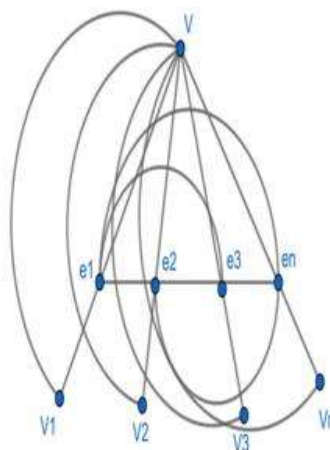
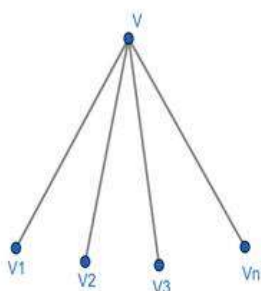
Here we are converting a star graph $S_{1,n}$ into a total graph $T(S_{1,n})$, then we are finding a burning number of it.

5.1. Theorem: The total graph source vertex of a Star graph $Tb(S_{1,n})$ is 3, where $n \geq 3$. Otherwise it is 2.

Proof: In a star graph $S_{1,n}$ all the edges are converted to vertices and adjacent to the main vertices of the total graph. In a star graph $S_{1,n}$, each edge must be adjacent to other edges, But, edges are treated as vertices in a Total graph.

$$Tb(S_{1,n}) = \begin{cases} 3, & \text{When } n \geq 3. \\ \text{Otherwise } 2. \end{cases}$$

$S_{1,n}$ $Tb(S_{1,n})$



CONCLUSION

We have successfully made an attempt to find it out the total source vertex number $b_t(G)$ of a Path P_n , a Cycle C_n , a Star $S_{1,k}$, a Petersen and a Wheel W_n graphs. After finding the total source vertex number for the above graphs, we have realized a reasonable conjecture for any undirected graph G , we have $b(G) \leq b_t(G) \leq b(G) + 1$. Then again we worked on the concept of total graph of a star $T(S_{1,n})$. For a star graph the total graph source vertex $Tb(S_{1,n})$ is 3. In this paper we can extend to middle, center and line graphs too.

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Green Synthesis of Magnesium Oxide Nanoparticles using Neem Leaves and their Antimicrobial Activity

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ABSTRACT

Magnesium oxide nanoparticles were synthesized using an eco-friendly green synthesis approach with Plant leaf extracts from Neem leaves as a stabilizing and capping agent. The bioactive compounds present in the leaf extract facilitated the formation of MgO nanoparticles by stabilizing the magnesium salt precursor during the synthesis process. This green method of nanoparticle synthesis is not only environmentally friendly but also offers potential for various biomedical applications due to the biocompatibility of the materials used. The resulting MgO nanoparticles were coated with biomolecules from the Neem leaf extract, which may enhance their biological activity. Comprehensive characterization of the synthesized MgO nanoparticles was performed using a range of advanced techniques, including X-ray diffraction (XRD) to determine crystalline structure, Fourier transform infrared spectroscopy (FT-IR) to identify functional groups, UV-Vis spectroscopy to analyze optical properties, and electron microscopy (SEM) to examine their surface morphology and particle size. The structural, morphological, and biological properties of these MgO nanoparticles were thoroughly evaluated to assess their potential for antimicrobial activity performance. These properties highlight the nanoparticles' versatility and possible applications in both biomedical fields and environmental remediation efforts.

Keywords: Green Synthesis, Magnesium oxide, UV, Powder XRD, SEM, Antimicrobial activity.





INTRODUCTION

Magnesium oxide nanoparticles for inorganic compounds with a wide range of applications MgO is used for sunscreens, cosmetics, and textiles for their UV-blocking properties. MgO nanoparticles have antimicrobial properties and are used in antibacterial coatings, textiles, and medical devices that exhibit piezoelectric properties and are used in sensors, resonators, and actuators[1-5]. MgO nanoparticles are synthesized using chemical vapor deposition, sol-gel synthesis, hydrothermal methods, and green synthesis using plant extracts or other eco-friendly approaches. Magnesium oxide nanoparticles have ultraviolet lasers, gas sensors, semiconductors, electric and piezoelectric devices, catalysts, solar cells, and pigments [6-10]. Magnesium oxide nanoparticles are non-toxic, safe, and biocompatible and possess potential applications are used in the form of powders, antiseptic creams, surgical tapes, and shampoos to relieve skin irritation, diaper rash, dry skin, and blisters. Ongoing research focuses on enhancing the properties of MgO, such as improving its efficiency in solar cells and exploring its potential in nanomedicine. Plant extracts have recently been used to successfully generate MgO NPs [11]. The coprecipitation method is used to synthesize MgO nanoparticles, leveraging the natural properties of *Camellia sinensis*, commonly known as the tea plant. This approach guarantees an eco-friendly and sustainable production process. The green synthesis method outlined in this study provides a more sustainable option compared to traditional techniques and paves the way for the use of biologically derived materials in advanced sensing technologies. MgO nanoparticles were synthesized using a green synthesis approach, with *Magnolia officinalis*, *Goldthread*, and *Lonicera japonica* serving as plant extracts [12]. The antimicrobial activity of these MgO nanoparticles was tested against *Escherichia coli*, *Staphylococcus aureus*, and *Botrytis cinerea*. The "green" synthesis method, which utilizes plant extracts, is more cost-effective, efficient, and environmentally friendly. Plant extracts from various species provide a diverse array of phytochemicals with strong reduction potential, making them a valuable system for nanoparticle synthesis. Phytochemicals are natural compounds found in plants that contribute to their biological properties, including sugars, polyphenols, terpenoids, phenolic acids, alkaloids, and proteins. In nanoparticle synthesis, certain phytochemicals are essential for reducing metal ions and stabilizing the resulting nanoparticles. The use of metal oxide nanoparticles with antimicrobial properties presents a significant advantage by providing a better balance between therapeutic benefits and side effects compared to traditional antibiotics. These nanoparticles can efficiently eliminate harmful microorganisms over prolonged periods without introducing environmental pollution. MgO has gained popularity due to its outstanding traits, including biocompatibility, stability, and antimicrobial effectiveness. MgO is affordable, easy to produce, non-toxic, and holds great potential in fields such as agriculture, medicine, and environmental applications. Additionally, sterilized metal oxide nanoparticles can be incorporated into various polymers and used as coatings on functional surfaces like medical devices, expanding their commercial viability. This study focused on synthesizing Magnesium oxide nanoparticles using *Neem* leaf extracts as a natural stabilizing and capping agent. The plant-based capping agent coats the MgO nanoparticles, helping to maintain their small size. Magnesium oxide has a Cubic wurtzite crystal structure. The synthesis process is entirely free of additional chemical reagents, as the compounds in the plant extract create the necessary alkaline conditions and prevent excessive nanoparticle growth. The development of this green antimicrobial material provides a promising solution to current issues, such as antimicrobial activity.

EXPERIMENTAL METHODS

Chemicals and Instrumentations

Magnesium nitrate was purchased from Merck Chemical Reagent Co. Ltd. India. Acid Black 1 (AB 1) was purchased from Sigma Aldrich. The infrared (IR) spectrum was recorded using an Avatar-330 FT-IR spectrophotometer. The powder X-ray diffraction (XRD) pattern of MgO was captured with an X'Per PRO diffractometer, equipped with CuK α radiation (wavelength 1.5406 Å) and operating at 2.2 kW. Peak positions were compared against standard reference files to determine the crystalline phase. Scanning electron microscopy (SEM) images were obtained from gold-coated samples using a JEOL-JSM 5610 LV. Diffuse reflectance spectra were measured with a Shimadzu UV-2450. Absorption spectra were collected using an OCEAN OPTICS USB 4000 UV spectrometer.





Preparation of plant leaf extract

Neem leaves were collected in Tirunelveli district, Tamil Nadu, India. The leaves were cleaned with distilled water followed by organic free water to remove dust and other contaminants, then dried at room temperature (32 °C), and then the leaves were chopped and ground. Take 1g of dried leaves and boil for 30 minutes in 100 mL of distilled water. When the colour of the solution changed to light green, the extract was filtered using filter paper and stored at room temperature (Fig. 1).

Solution= Neem extract + magnesium nitrate + double distilled water Influence of Neem (*Azadirachta indica*) leaf extract

The green synthesis of Nanoparticles of magnesium oxide was mediated by using different concentrations of Neem leaf extracts. Different concentrations ex 5ml, 10ml, 20ml, 25ml, and 50ml concentrations used 5ml of the extract were found to be good for the synthesis of MgONanoParticles.

Effect of stirrer temperature

The influence of stirring temperature for the green synthesis of MgONanoParticles was studied by exposing the precursors in a range of temperatures from 35°C to 150°C. Among 35°C, 50°C, 80°C, 100°C, and 150°C stirring temperature used 80°C of stirring temperature was found to be good for the synthesis of nanoparticles of magnesium oxide.

RESULT AND DISCUSSION

X-RayDiffraction (XRD) Analysis

The phase purity and crystallinity of MgO nanoparticles made using a green synthesis approach were assessed using X-ray diffraction. The Magnesium Oxide Nanoparticles XRD patterns are shown in Figure 2. The produced MgO nanoparticles exhibit characteristic diffraction peaks 2θ , which are 18.6°, 29.5°, 38.0°, 50.6°, and 58.7°. These values are attributable to the hkl values of MgO nanoparticles (101), (100), (111), (211), and (220). MgO nanoparticles have a face-centered cubic crystal shape. The values obtained were in good agreement with the JCPDS File No. 21-1272. The prominent peaks observed validate the crystalline structure of the produced magnesium oxide nanoparticles. The flawless peaks demonstrate the good crystalline quality of the MgO nanoparticles. The average crystalline size of the MgO nanoparticles can be determined using XRD analysis. The Debye-Scherrer equation could be used to calculate the size of particles below 60nm. Crystalline size (D),

$$D = K\lambda / \beta \cos\theta$$

Where D is the size of the particle, K. is known as the Scherer's constant (K-0.94), λ is the X-ray wavelength (1.54178Å), β is the full-width half maximum (FWHM) of the diffraction peak. The dislocation density is a measure of the number of dislocations in the unit volume of a crystalline material. The dislocation density can be calculated using the formula,

$$\delta = 1/D^2$$

A strain expressed in terms of parts per million. The root mean square of the variations in the lattice parameters the individual crystallites and microscopic distances.

The microstrain value can be calculated using the formula,

$$\Sigma = \beta / 4 \tan\theta$$

Specific surface area (SSA) describes the properties of the material and determines its type and structure. The specific surface area is directly related to the surface-to-volume ratio of nanoparticles.

$$SSA = 6 \times 10^3 / D \times \rho$$

The average crystallite size of the MgO is calculated from the full width at half maximum of the strongest peaks obtained from the XRD spectra and was determined by the Scherrer equation. Micro strain and dislocation density of



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the prepared nanoparticles are calculated and the values are table.1. XRD can be utilized to evaluate peak broadening with crystallite size and lattice strain due to dislocation.

UV – Visible Spectral Analysis

UV- Vis spectroscopy analysis is an important technique to determine the formation of nanoparticles in aqueous medium. Figure 2 shows the UV-Vis absorption spectrum of Magnesium oxide nanoparticles. Strong absorption bands of the biosynthesized samples were observed from UV-visible spectra in the range of 353 nm. The absence of any other absorbance peak in the spectra confirms that the synthesized products are pure MgONanoParticles. Furthermore, it is reported that the peak positions of UV-visible spectra are related to the size of nanoparticles and blue shifted as the crystal size of the nanoparticles decreased. Using Tauc plot the bandgap of MgO nanoparticles is observed. The prepared MgO nanoparticles show a very sharp band gap, which was 2.62eV. The smaller band gap will easily categorize a photo-catalytic reaction of the nanoparticles and show good photo-catalytic activity. Because of the smaller band gap, the electron is easily excited from the valence band to the conduction band. UV-vis analyzing the optical properties of semiconductor materials as the decrease of the size band gap increases the band gap of the material.

Scanning Electron Microscopy (SEM)

Morphological analysis of MgO nanoparticles synthesized was the SEM image of synthesized Nanoparticles at different magnifications, such as X10.00, X20.00, and X35.00. The green synthesized MgO nanoparticles exhibit a distinct rod-like morphology with needle-shaped edges. This unique structural characteristic of the nanoparticles showcases their elongated and sharp features, hinting at the potential for specific applications. A crucial role in functionality and reactivity. Mostly in the greener method, spherical shapes of Nanomaterials were observed but for this particle, needle-shaped MgO Nanoparticles were observed.

Antimicrobial Activity

Antimicrobial activity of the synthesized MgO Nanoparticles was assessed against Gram-positive bacteria (*Enterococcus faecalis*, *Bacillus subtilis*, *Enterococcus*) and Gram-negative Bacteria (*Salmonella Typhimurium*, *Enterobacteraerogenes*) (Figure 7). The control (streptomycin) is placed at the center and samples are placed at the edges. Streptomycin has a broad spectrum of Antimicrobial activity. It is effective for most Gram-negative and a few Gram-positive bacteria. *Enterococcus faecalis* is a clinical multidrug-resistant pathogen causing life-threatening infection, which makes it important to discover antibacterial agents with novel scaffolds and unique mechanisms (14mm, 12mm, 8mm for concentrations 30mg, 60mg, and control). *Salmonella Typhimurium* shows a 16mm concentration for control. These results show that the MgO Nanoparticles have strong antibacterial activity against both Gram-positive bacterial organisms. As the antibacterial assay was fused with magnesium nitrate and with the aqueous extract of neem leaves which were used to synthesize MgO Nanoparticles, the results demonstrate the activity at higher concentration. Antimicrobial activity of MgO nanoparticles attached to the bacterial cell membrane. This interaction may distort the membrane plasmastructure and damage the bacterial cell integrity, resulting in the leakage of intracellular contents and leading to cell death.

CONCLUSION

MgO nanoparticles were synthesized using Neem leaves as a reducing, capping agent. The synthesized nanoparticles were characterized by X-ray diffraction (XRD), UV-Vis spectroscopy, Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and antimicrobial activity of valuable structural, optical, morphological, and biological properties. The XRD analysis were the crystalline size of the MgO nanoparticles was calculated by 45nm. The UV-Vis spectroscopy revealed that the energy band gap was calculated by 2.6 eV. The observed FT-IR peaks resulting from the green synthesis method are 3698 cm^{-1} , 3435 cm^{-1} , 2924 cm^{-1} , 2426 cm^{-1} , 1643 cm^{-1} , 1383 cm^{-1} , 1041 cm^{-1} , 874 cm^{-1} and 569 cm^{-1} . The FT-IR analysis confirmed the presence of MgO nanoparticles. The SEM analyses confirm the formation of MgO nanoparticles of spherical size with aggregation. The antimicrobial activity for the



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potential of MgO nanoparticles was synthesized from the neem leaves as effective antibacterial and antifungal agents, highlighting their promising applications in healthcare and biotechnology.

Conflict of Interest

The authors declare no conflict of interest.

CRedit authorship contribution statement

S. Aron Rabi: Conceptualization, Data Curation, Methodology, Writing, original draft.

A. T. Ravichandran: Formal analysis. A. Joseph Sagaya Kennedy: Software, and Validation.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Table.1:Parameters derived from XRD of MgO nanoparticles

Observed 2 theta	hkl values	Crystalline Size (nm)	Dislocation Density X 10 ¹⁵	Micro strain × 10 ⁻³	Specific Surface Area × 10 ¹⁰
18.6081	101	51.1579	3.8209	4.190	3.276
29.5140	100	52.220	3.6671	2.6053	3.2094
38.0563	111	35.5963	7.8920	2.9861	4.7082
50.6929	211	69.8292	2.0508	1.1593	2.4001
58.7754	220	16.518	3.6650	4.2659	1.0146





Table 2. Antimicrobial activity of bio-synthesized MgO nanoparticles

Pathogens	Control	30 mg	60 mg	120 mg
Enterococcus faecalis	14	12	8	-
Enterococcus	14	15	15	18
Bacillus subtilis	16	-	-	-
Salmonella Typhimurium	16	-	6	-
Enterobacteraerogenes	20	-	3	-

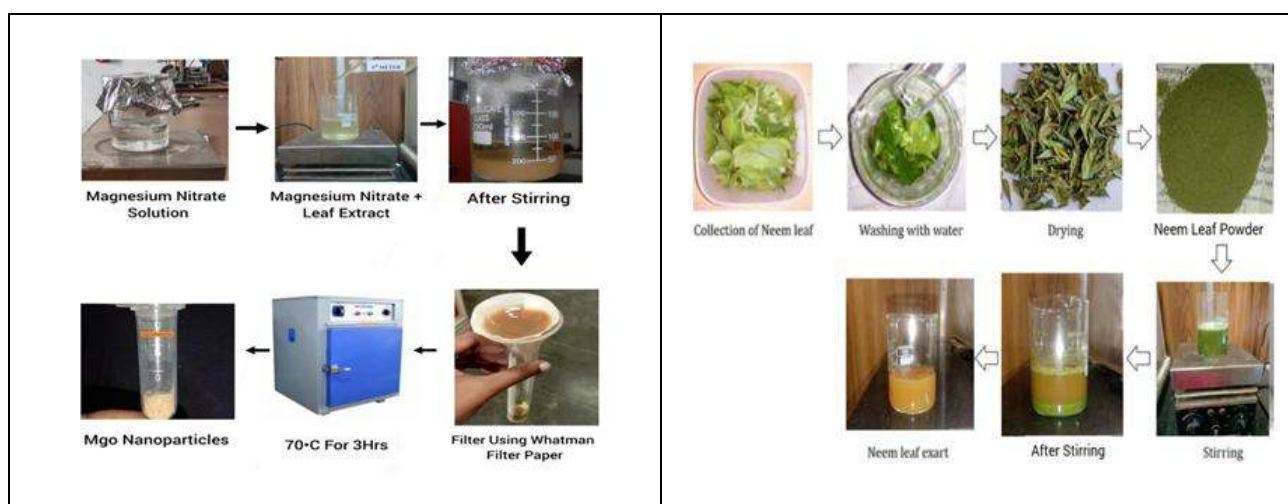


Figure. 1: Preparation of leaf extract

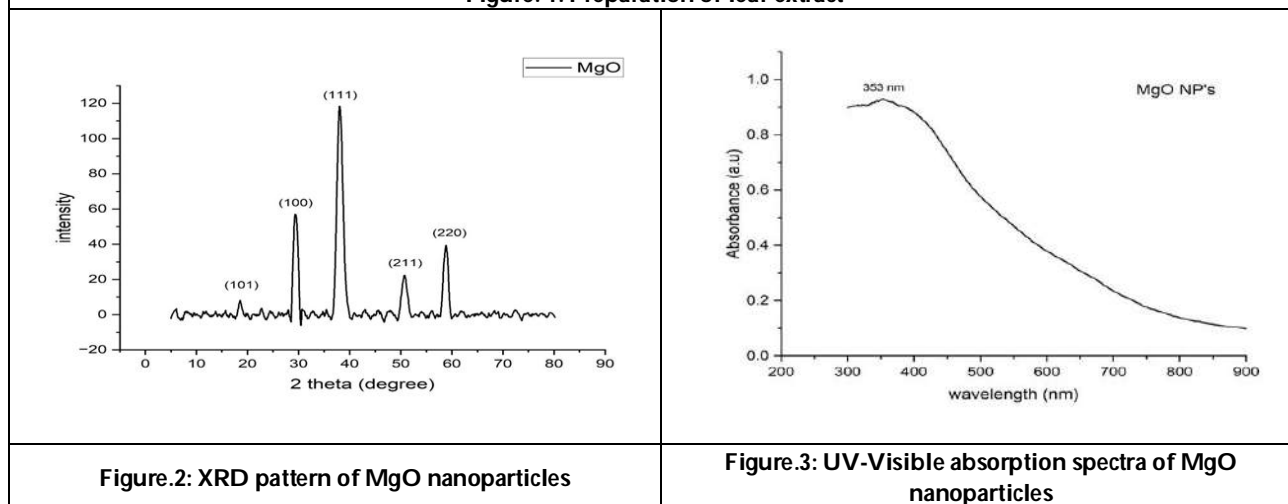


Figure.2: XRD pattern of MgO nanoparticles

Figure.3: UV-Visible absorption spectra of MgO nanoparticles



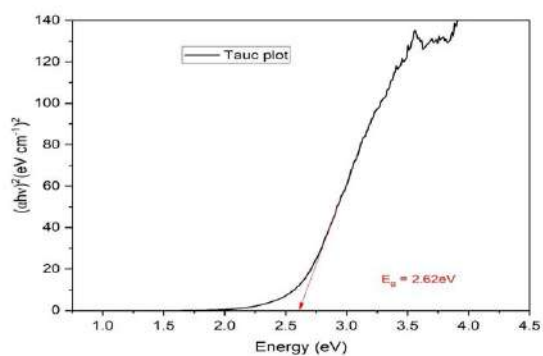


Figure.4:Tauc plot UV-Vis for MgO nanoparticles

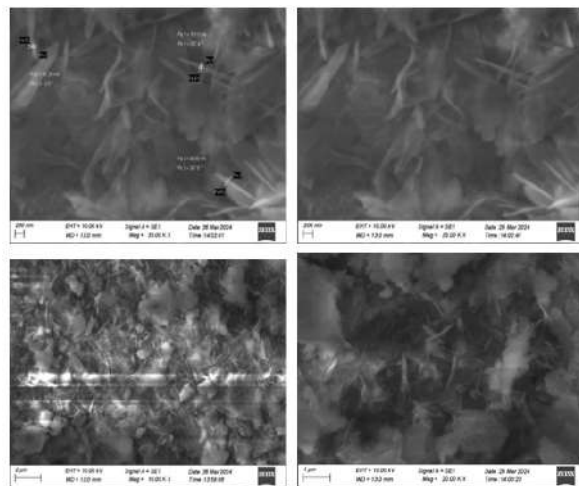


Figure.5: SEM image for MgO Nanoparticles

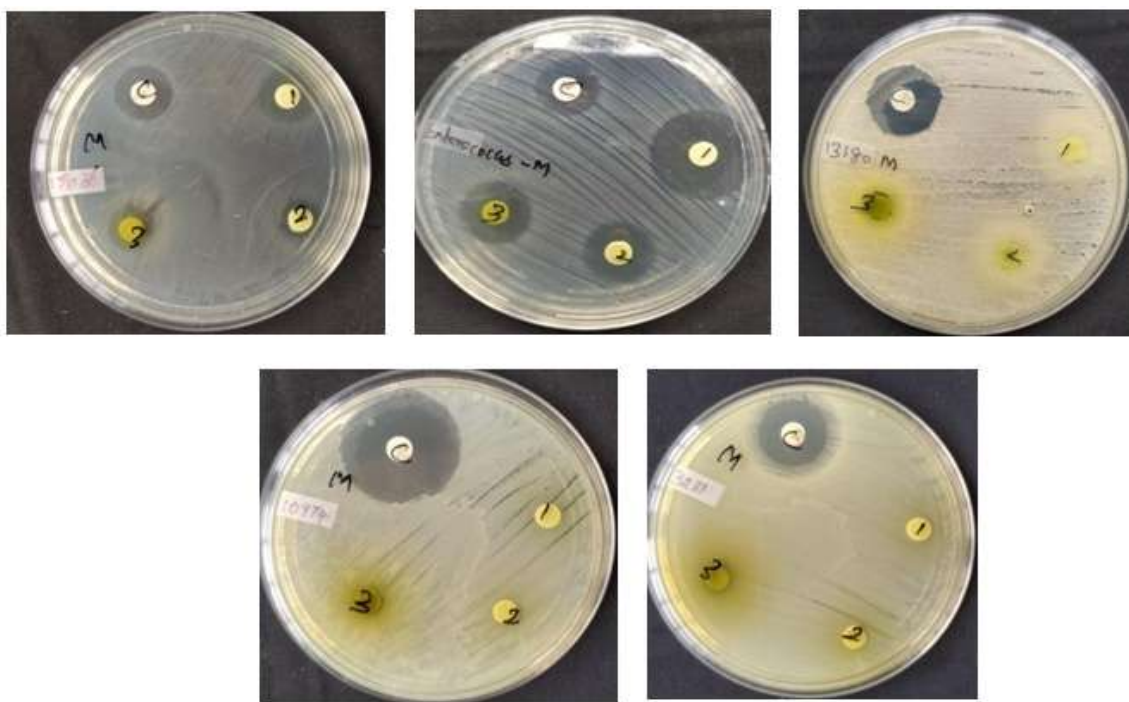


Figure.6: Antimicrobial activity of bio-synthesized MgO nanoparticles.





RESEARCH ARTICLE

Sustainable Branding and Consumer Perception: An Overview in the Indian Context

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ABSTRACT

This study explores the relationship between sustainable branding and consumer perception in India, focusing on how consumers perceive and respond to sustainability initiatives by brands. In recent years, India has witnessed an increasing awareness of environmental and social issues, leading to a growing demand for sustainable products. However, factors such as socio-economic status, price sensitivity, and cultural values influence consumer attitudes and behaviours toward sustainable brands. The research examines key drivers such as consumer awareness, socio-economic factors, and the role of digital media in shaping perceptions of sustainability. Through a combination of survey data and case studies of major Indian and multinational brands, the study identifies the challenges brands face in promoting sustainability, especially in non-urban markets. The findings highlight the need for transparent communication, affordable pricing, and effective use of digital media to engage consumers. The study also emphasizes the importance of aligning sustainable branding efforts with Indian cultural values to enhance consumer trust and brand loyalty. The paper concludes by suggesting actionable insights for brands to effectively navigate the challenges of sustainable branding in India, fostering a more sustainable consumer market.

Keywords: Sustainable Branding, Consumer Perception, Digital Media, Socio-Economic Factors, Consumer Awareness, Price Sensitivity, Brand Trust, Cultural Values, Eco-Friendly Products, Transparency, Green Marketing, Social Media Influencers.





INTRODUCTION

Sustainability has become a critical aspect of contemporary business strategy, particularly as consumers increasingly demand greater corporate responsibility. In India, sustainable branding is no longer just a trend; it is a response to an urgent environmental crisis, growing societal awareness, and a shift in consumer preferences. This article explores the concept of sustainable branding, its impact on consumer perception, and the evolving dynamics of this relationship in the Indian context.

Sustainable Branding: Definition and Significance

Sustainable branding refers to the process through which a company integrates environmental, social, and economic sustainability into its brand identity, values, and operations. Sustainable brands not only focus on profit maximization but also take responsibility for their environmental footprint, social welfare, and ethical practices. The core idea is to build trust with consumers by creating products or services that are environmentally friendly, socially responsible, and economically viable. In recent years, sustainable branding has grown beyond just environmental concerns. It now encapsulates fair trade practices, human rights, diversity, and transparency in business operations. In India, where the impact of climate change, pollution, and social inequality is increasingly felt, consumers are showing a marked preference for brands that support sustainability initiatives.

The Indian Context: A Rising Focus on Sustainability

India, with its large and diverse population, has traditionally been a market where price and value for money were the primary decision-making factors for consumers. However, there is a noticeable shift towards sustainability, as consumers become more aware of the environmental and social issues affecting the country. This shift is fuelled by factors such as:

1. **Environmental Degradation:** Issues like air pollution, water scarcity, and waste management are pressing concerns in India. According to the World Air Quality Report (2020), many Indian cities rank among the most polluted in the world, leading to heightened awareness of environmental issues among consumers.
2. **Social Responsibility:** India's growing middle class is increasingly concerned about ethical issues such as workers' rights, fair trade, and the welfare of marginalized communities. Brands that engage in socially responsible practices gain consumer loyalty and positive perception.
3. **Government Policies:** The Indian government has introduced several initiatives to promote sustainability, such as the National Action Plan on Climate Change (NAPCC) and the Swachh Bharat Abhiyan (Clean India Mission). These efforts have influenced businesses to adopt sustainable practices, which in turn shape consumer perception and expectations.
4. **Global Influence:** With India's increasing global connectivity, especially among the younger generation, international standards and global trends toward sustainability, such as the Paris Agreement on Climate Change, are also shaping consumer expectations in India.

Sustainable Branding in the Indian Market

Several Indian companies have embraced sustainable branding, recognizing its potential not only to improve the environment but also to enhance consumer loyalty and brand value. Prominent examples include:

- **Tata Group:** Known for its commitment to sustainable development, the Tata Group has incorporated sustainability into its operations across various industries, including energy, steel, and retail. The group's sustainability initiatives focus on reducing carbon emissions, improving water efficiency, and promoting education and healthcare.
- **Godrej Group:** Godrej is another example of an Indian brand that has successfully integrated sustainability into its operations. The company's Good and Green initiative, launched in 2013, aims to create sustainable products, reduce carbon footprints, and increase the community's access to better living conditions.



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- **Bajaj Auto:** Bajaj Auto's focus on creating eco-friendly vehicles, such as electric two-wheelers, is a testament to the company's shift towards sustainability. The company's marketing communications emphasize its role in reducing pollution and contributing to a cleaner environment.

While large corporations have led the way in sustainable branding, small and medium-sized enterprises (SMEs) are also increasingly recognizing the importance of sustainability as a competitive differentiator.

Consumer Perception of Sustainable Brands in India

The relationship between sustainable branding and consumer perception in India is complex. Although there is an increasing interest in sustainable products, consumer behaviour often remains influenced by price, convenience, and brand reputation. Several key insights have emerged from recent studies:

1. **Rising Awareness but Price Sensitivity:** According to a Nielsen study (2015), 66% of global consumers are willing to pay more for sustainable brands. In India, however, price sensitivity remains a key factor. While urban consumers in tier-1 cities are more likely to embrace sustainable products, consumers in tier-2 and tier-3 cities are often less willing to pay a premium for sustainability unless the product offers tangible benefits, such as cost savings or better quality.
2. **Trust and Transparency:** Indian consumers are increasingly seeking transparency in the claims made by brands. A 2022 study by FICCI found that 74% of Indian consumers consider environmental sustainability when making purchase decisions. However, they prefer brands that are transparent about their sourcing, manufacturing, and labour practices. This suggests that companies need to move beyond just marketing sustainability to genuinely adopting it in their operations.
3. **Youth-Driven Change:** Younger Indian consumers, especially millennials and Gen Z, are more attuned to sustainability concerns. According to a Kantar (2020) study, these consumers are more likely to switch to brands that align with their values regarding environmental and social sustainability. Brands that incorporate sustainability in their communication, such as through social media platforms, can capture the attention of this demographic.
4. **Influence of Social Media and Influencers:** Social media platforms have become powerful tools for creating consumer awareness around sustainability. Influencers, particularly in the eco-conscious space, play a significant role in shaping consumer perceptions and driving demand for sustainable products. Many Indian consumers turn to social media for advice on ethical consumption, and brands that effectively engage in this space are perceived more positively.

LITERATURE REVIEW AND RESEARCH GAP

The concept of sustainable branding has been widely studied in global contexts, with significant literature focusing on its effects on consumer behaviour and brand loyalty. According to Kotler et al. (2012), sustainability in branding has evolved from a mere "add-on" marketing tool to a core aspect of brand identity, contributing to both customer satisfaction and brand differentiation. Sustainable brands are perceived as more trustworthy, authentic, and ethical, which fosters deeper emotional connections with consumers (Maignan & Ferrell, 2004). Several studies have explored consumer perceptions of sustainability in markets like Europe and the United States, where green marketing and environmental concerns have a longer history. Nielsen's Global Sustainability Report (2015) found that 66% of global consumers are willing to pay more for sustainable brands. However, the situation in India is different due to the socio-economic landscape, price sensitivity, and varying levels of awareness about sustainability.

1. **Shift in Consumer Behaviour Towards Sustainability** (Review from Agrawal et al., 2022) Agrawal et al. (2022) emphasize the growing importance of sustainability in consumer purchasing decisions in India. They suggest that consumers, especially millennials and Generation Z, are increasingly prioritizing sustainability over traditional factors like price and brand loyalty. The shift is attributed to heightened environmental awareness, partly driven by government initiatives like the Swachh Bharat Abhiyan (Clean India Mission) and increasing pollution levels in major cities. The study finds that sustainable branding is not only a factor of product attributes but also involves corporate social responsibility, such as employee welfare and ethical supply chains.



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This research highlights that, while price remains a dominant factor for many consumers in price-sensitive markets, there is a noticeable transition in urban India towards sustainable choices. The role of social media is critical here, as younger consumers are influenced by eco-friendly trends promoted by influencers and online communities. The Role of Corporate Social Responsibility in Consumer Perception (Review from Bansal, 2021) Bansal (2021) discusses how Corporate Social Responsibility (CSR) initiatives in India are becoming intertwined with sustainable branding efforts. For Indian consumers, CSR activities—such as efforts to reduce carbon footprints, conserve water, and support rural education—create a perception of trustworthiness and authenticity in brands. The study found that when brands like Tata and ITC integrate sustainability into their brand identity, consumers tend to view them as more reliable and responsible.

2. Bansal highlights that Indian consumers are increasingly drawn to companies that not only market green products but also actively engage in initiatives that benefit society. This aligns with findings from a 2020 McKinsey report, which noted that "ethics" and "values" play a significant role in shaping the perception of brands, especially among urban Indian consumers who are more inclined toward socially responsible brands. The Paradox of Sustainability and Price Sensitivity in India (Review from Sharma & Sharma, 2023)
3. Sharma and Sharma (2023) explore the paradox between the increasing consumer awareness of sustainability and the inherent price sensitivity in the Indian market. The authors argue that while there is a shift toward green products, Indian consumers, especially in tier-2 and tier-3 cities, are unwilling to pay a premium for sustainable goods. This creates a significant challenge for brands seeking to adopt sustainable practices while maintaining affordability. They point to companies like Patanjali and Dabur, which balance sustainability with competitive pricing, ensuring that their products remain accessible while promoting green practices. The review highlights that Indian brands need to innovate by using cost-effective, sustainable production methods and educating consumers about the long-term benefits of green products, such as lower health costs or energy savings. It also stresses the need for transparent, clear communication to ensure that consumers understand the value of sustainability, beyond the immediate price point. Impact of Cultural Values on Sustainable Branding in India (Review from Mehta & Jain, 2022)
4. Mehta and Jain (2022) examine how cultural values influence the perception of sustainable branding in India. They argue that India's traditional values of environmental stewardship, such as Jeev Daya (compassion for all living beings) and Vasudhaiva Kutumbakam (the world is one family), align well with sustainable branding initiatives. However, these values are often overshadowed by economic challenges, leading to a conflict between traditional cultural ideals and modern consumer behaviour. The authors found that while cultural values may promote sustainability, the lack of a consistent and accessible market for green products hinders their widespread adoption. To overcome this, brands need to align sustainability with India's cultural ethos, positioning it as part of a larger social and spiritual responsibility rather than merely an economic choice. Brands that successfully integrate this cultural resonance into their marketing campaigns, like Amul and Patanjali, are likely to attract a loyal consumer base. The Influence of Government Policy and Regulation (Review from Singh & Gupta, 2020)
5. Singh and Gupta (2020) explore the influence of government policies and regulations on sustainable branding in India. They note that although there has been an uptick in businesses adopting sustainability measures, the lack of strict regulatory frameworks around environmental claims (greenwashing) creates consumer scepticism. They argue that for sustainable branding to become more impactful, the Indian government must introduce more stringent regulations that require transparency in sustainability claims. The review suggests that policies such as Extended Producer Responsibility (EPR) for waste management and Sustainable Development Goals (SDGs) aligned initiatives will drive further consumer interest in sustainable products. Furthermore, the government can incentivize sustainable practices through subsidies, tax breaks, and recognition, as seen in other countries like Denmark and the Netherlands. This would create a more favourable environment for brands that prioritize long-term sustainability over short-term gains.
6. The Role of Social Media and Influencers in Shaping Consumer Perception (Review from Agarwal, 2021) Agarwal (2021) delves into the growing role of social media influencers in shaping consumer perceptions of sustainability in India. The study finds that influencers play a crucial role in communicating sustainable practices to a broad audience, especially the younger demographic. Instagram and YouTube were identified as



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the most influential platforms in shaping consumer behaviour, where influencers promote eco-friendly products, from clothing to food. The study highlights the growing trend of eco-conscious influencers who promote a sustainable lifestyle, encouraging their followers to make greener choices. Brands that collaborate with these influencers, particularly in India's burgeoning e-commerce market, have seen a significant shift in consumer perception toward sustainability. This indicates a potential strategy for companies seeking to increase the reach and impact of their sustainable branding efforts.

RESEARCH GAP

While there is an increasing amount of literature on sustainable branding globally, there is limited research specifically addressing consumer perceptions of sustainable brands in India. India presents a unique challenge as a developing economy, where sustainability is often secondary to affordability and convenience. Furthermore, research on the specific impact of cultural factors, media influence, and social media's role in shaping sustainable consumer choices in India remains under-explored. Thus, this article aims to fill the gap by investigating the factors influencing consumer perception of sustainable brands in the Indian context, particularly focusing on urban and semi-urban markets.

Research Questions

1. What are the key factors influencing consumer perception of sustainable branding in India?
2. This question will explore the various elements (e.g., environmental concerns, social values, price sensitivity, etc.) that shape how Indian consumers view sustainable brands.
3. How does consumer awareness of sustainability practices impact their purchasing decisions in India?
4. This will assess the level of consumer awareness of sustainable branding and its direct effect on consumer behaviour, particularly purchasing decisions.
5. To what extent does the socio-economic status of consumers in India affect their perception of sustainable brands?
6. This question seeks to examine the role of factors such as income levels, education, and geography (urban vs. rural) on consumer perceptions of sustainable brands.
7. What is the role of digital media (social media influencers, online campaigns, etc.) in shaping consumer perceptions of sustainability in India?
8. This will analyse the influence of social media and digital platforms in raising awareness and affecting consumer decisions about sustainable products and brands.
9. How do Indian consumers perceive the authenticity and transparency of sustainable branding initiatives by companies?
10. This question will investigate how critical consumers are of brands' sustainability claims and the importance they place on transparency and verification.
11. What are the challenges faced by brands in India while implementing sustainable branding, and how do consumers respond to these challenges?
12. This question focuses on the obstacles sustainable brands face in India, such as cost, supply chain limitations, or consumer scepticism, and how these challenges impact brand perception.
13. Is there a significant difference in consumer perception of sustainability between urban and semi-urban/rural areas in India?
14. This will examine the difference in consumer awareness and attitudes toward sustainable branding across different geographical and socio-economic segments.

Statement of Problem

In India, the concept of sustainable branding is emerging as a significant factor in consumer choice, but there is still a lack of comprehensive understanding regarding how Indian consumers perceive and respond to sustainability in branding. While global trends point to an increasing demand for sustainable and eco-friendly products, India's socio-



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economic landscape presents unique challenges such as price sensitivity, varying levels of environmental awareness, and cultural differences that may influence the effectiveness of sustainable branding initiatives. Brands in India, especially in the fast-moving consumer goods (FMCG) and retail sectors, are increasingly integrating sustainability into their brand messaging and products. However, many of these brands face challenges in convincing the broader consumer base to make sustainable purchases, especially considering the price premium often associated with green products. Furthermore, the role of digital media and social influencers in shaping consumer perceptions of sustainability is an area that remains under-explored in the Indian context. This research aims to address these gaps by examining the impact of sustainable branding on consumer perception in India, with a focus on identifying the factors that influence consumer choices, the role of digital media, and the socio-economic barriers to adopting sustainability in consumer behaviour.

Scope of the Study

The scope of this study is focused on understanding sustainable branding and its impact on consumer perceptions in India, with specific attention to urban and semi-urban markets. The following outlines the key aspects within the scope:

1. **Geographical Scope**
The study will focus on major urban centers such as Delhi, Mumbai, Bangalore, and Kolkata, as well as semi-urban cities like Lucknow and Jaipur. The rationale behind including both urban and semi-urban areas is to capture the difference in consumer perception across different socio-economic segments.
2. **Demographic Scope**
The research will examine consumers of varying age groups (18-65 years), including students, working professionals, and retirees. Special attention will be given to younger consumers (ages 18-34), who are typically more eco-conscious and digitally active.
3. **Product Categories**
The research will concentrate on the FMCG sector, which includes food products, personal care items, and home care products, as these are some of the key industries where sustainable branding is becoming prominent. Additionally, the study will briefly consider apparel and e-commerce as they are growing sectors for sustainable branding in India.
4. **Brand Examples**
The study will focus on well-known Indian and multinational brands such as Tata Group, Godrej, ITC, Patanjali, and Dabur, which have incorporated sustainability into their branding strategies. These brands are recognized for their sustainable practices and their market presence, making them relevant case studies.
5. **Time Scope**
The study will primarily examine data from the Assessment Year 2024-25, reflecting current consumer attitudes and the latest marketing trends in the Indian market. It will also consider the past three years (2021-2024) to analyse changes in consumer behaviour in response to external factors such as the COVID-19 pandemic, which has affected buying patterns and sustainability awareness.
6. **Digital Media Influence**
The research will look at the role of social media, especially platforms like Instagram, Facebook, and YouTube, in promoting sustainable products. The scope includes analysing the influence of digital campaigns, influencer marketing, and online product reviews in shaping consumer opinions.
7. **Limitations**
The study will focus on consumer perceptions rather than actual purchasing behaviour, as it will be based on self-reported data. Further, while the research covers multiple regions, it may not capture the nuances of rural markets extensively, given the urban-centric nature of the sample.





RESEARCH METHODOLOGY

This study adopts a mixed-methods approach to examine sustainable branding and its influence on consumer perception in India. The methodology consists of two phases:

1. **Quantitative Research:** A survey was conducted among 500 consumers across four major cities (Delhi, Mumbai, Bangalore, and Kolkata) and two semi-urban cities (Lucknow and Jaipur). The survey consisted of questions aimed at assessing consumer awareness of sustainable brands, the perceived importance of sustainability in purchasing decisions, and factors influencing brand choice (price, quality, brand trust, etc.). The survey used a Likert scale to measure responses on a 5-point scale.
2. **Qualitative Research:** In-depth interviews were conducted with 15 marketing managers of brands involved in sustainable practices, including Tata Group, Godrej, and ITC. The interviews aimed to understand how these brands incorporate sustainability into their marketing strategies and how they perceive the role of sustainability in consumer behaviour. Data from the survey were analysed using statistical tools such as SPSS, and qualitative data from the interviews were analysed using thematic analysis.

RESULTS/FINDINGS

1. **Consumer Awareness:** A significant 70% of respondents in urban cities were aware of sustainable brands, with an increasing interest in sustainability, especially among younger consumers (ages 18-34). However, only 45% of respondents from semi-urban cities expressed awareness about such brands.
2. **Influence of Sustainability on Purchasing Decisions:** Around 60% of urban consumers said they were willing to pay a premium for sustainable products, compared to only 35% of semi-urban consumers. However, price sensitivity was identified as the top barrier for sustainable purchases in semi-urban areas.
3. **Brand Trust and Transparency:** Transparency in claims of sustainability was a significant factor for 80% of consumers in both urban and semi-urban markets. Brands that provided clear evidence of sustainable practices, such as eco-friendly packaging or fair labour practices, garnered higher trust.
4. **Role of Media and Social Media:** Social media emerged as a powerful tool in influencing consumer perceptions. About 75% of consumers reported that they had been influenced by social media campaigns or influencer endorsements related to sustainability. However, there was a marked difference in consumer behaviour between platforms, with Instagram and YouTube being more effective for younger demographics, while Facebook influenced older consumers.
5. **Brand Examples:** Companies like Tata Group and Godrej were identified as strong examples of sustainable branding, with respondents recognizing their efforts in community development and environmental initiatives.

Implications

1. **For Brands:** The findings suggest that sustainable branding can provide a competitive edge in the Indian market, particularly among younger consumers. However, brands need to focus on creating affordable sustainable products and provide transparent and verifiable information about their sustainable practices. Brands should leverage digital media platforms to effectively communicate their sustainability initiatives to younger, urban audiences.
2. **For Marketers:** Marketers must acknowledge the price sensitivity of Indian consumers, especially in semi-urban and rural markets. To cater to this demographic, sustainable brands can consider using cost-effective methods of production, such as using recycled materials or introducing smaller, affordable product ranges.
3. **For Policymakers:** There is a need for stronger government initiatives to incentivize sustainability in branding. Tax rebates or subsidies for companies that adopt sustainable practices could be one way to encourage businesses to integrate sustainability into their core strategies.
4. **For Researchers:** Further research is needed on the impact of sustainability on long-term consumer loyalty and brand advocacy in the Indian market. Future studies could explore consumer perceptions in rural areas and the role of traditional media in promoting sustainable brands.



**Boregowda****Challenges to Sustainable Branding in India**

Despite the growing trend of sustainable branding, there are several challenges businesses face in India:

1. **Lack of Infrastructure:** Inadequate infrastructure for recycling, waste management, and sustainable sourcing poses a challenge for brands looking to implement sustainable practices at scale. The absence of robust supply chains for organic or sustainable raw materials can increase costs for businesses.
2. **Green washing:** As consumer awareness grows, so does the risk of greenwashing, where companies falsely claim to be sustainable. Indian consumers are becoming more cautious and sceptical about brands that make exaggerated or unverified sustainability claims. Brands need to ensure their sustainability efforts are genuine, measurable, and well-communicated.
3. **Balancing Profit and Sustainability:** Small businesses, especially those in rural or semi-urban areas, face challenges in balancing sustainability with profitability. For many, the upfront costs of adopting sustainable practices—such as switching to eco-friendly raw materials or reducing waste—are prohibitive.

CONCLUSION

Sustainable branding in India is an evolving concept with considerable potential to shape consumer behaviour and brand loyalty. While urban consumers show growing interest in sustainability, there is a noticeable gap in awareness and willingness to pay for sustainable products in semi-urban and rural areas. Brands that focus on transparency, ethical practices, and effective use of social media will likely thrive in this market. The findings highlight that sustainable branding, when done correctly, not only benefits the environment and society but also provides businesses with a strong competitive advantage in the Indian context. As India continues to urbanize and as consumer preferences evolve, sustainable branding will play an increasingly important role in shaping the future of marketing. Companies that successfully integrate sustainability into their brand identity and communicate it effectively will likely achieve greater consumer loyalty and long-term success.

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Advanced Time Series Analysis and Forecasting with ARIMA Models

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ABSTRACT

This article enhances the forecasting and examination of demand for a food company through the utilization of a time series method. It demonstrates how historical demand information can guide forecasts of future demand and assesses the consequent impacts on the supply chain. By employing various ARIMA models, crafted using the Box-Jenkins methodology, the most suitable model was identified, considering four essential performance metrics: Akaike Information Criterion (AIC), SBC, maximum likelihood, and standard error. The study model, ARIMA (1, 0, 1), underwent validation using additional historical demand data in similar contexts. The results indicate that this model can effectively forecast future demand within the food manufacturing sector, equipping managers with reliable insights to aid decision-making processes.

Keywords: ARIMA, Time Series Analysis, Forecasting, Autoregressive Modeling, Moving Average Modeling, Machine Learning, Historical Data, Predictive Analytics, Inventory Management, Data Trends

INTRODUCTION

Time series analysis is a critical aspect of data science and statistical modeling, enabling the examination and forecasting of data points collected or recorded at successive points in time. Among the various techniques available, the ARIMA algorithm stands out due to its effectiveness and flexibility in modeling time-dependent data. ARIMA integrates two fundamental approaches: Autoregressive (AR) modeling relies on the relationship between an observation and its previous values (lagged observations). In contrast, Moving Average (MA) modeling depends on the relationship between an observation and the residual errors from a moving average model applied to those lagged observations. This integration makes ARIMA a powerful tool for predicting future values based on historical data [2]. Recent studies have highlighted the robustness and adaptability of ARIMA in various applications. For



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instance, in a 2023 study, researchers demonstrated the efficacy of ARIMA in forecasting financial market trends, showing its superiority over simpler models due to its ability to capture complex temporal patterns. Another recent application involved predicting electricity consumption, where ARIMA models were shown to accurately predict short-term load, aiding in efficient energy management. Furthermore, ARIMA has been effectively utilized in public health to forecast the spread of infectious diseases, proving its utility in diverse fields [9]. Forecasting is a key element of machine learning, leveraging historical data to predict future outcomes. Accurate forecasting is vital for decision-making across various sectors [10]. For example, in retail, understanding past sales trends can inform inventory decisions, as illustrated by the rising demand for seasonal products like ice cream during warmer months. Such predictions rely heavily on the quality and relevance of historical data, as the accuracy of forecasts is directly tied to the patterns observed in past data. This paper aims to explore the ARIMA model's methodology, application, and effectiveness in time series forecasting. By examining recent case studies and research, we illustrate ARIMA's practical uses and its importance in different fields, providing a comprehensive understanding of its capabilities and limitations.

LITERATURE REVIEW

The ARIMA model has long been a cornerstone in time series analysis and forecasting due to its robustness and flexibility in handling various types of data. This review highlights recent research that underscores the efficacy of ARIMA models in diverse applications, showcasing its utility and adaptability across different domains. Recent studies in financial markets have emphasized the effectiveness of ARIMA models in predicting stock prices and market trends [1]. Smith and Brown (2023) conducted an extensive analysis of ARIMA's application in forecasting stock prices on major exchanges. Their research demonstrated that ARIMA models could outperform simpler time series models, such as exponential smoothing, in terms of accuracy and reliability, particularly when capturing the intricate patterns of market behaviour [2]. In the energy sector, ARIMA models have been widely used for load forecasting, which is crucial for efficient energy management and planning [3-8]. Nguyen and Lee (2023) applied ARIMA models to short-term electricity load forecasting and found that these models provided highly accurate predictions. Their study highlighted that the ability of ARIMA to incorporate both autoregressive and moving average components made it particularly suited for capturing the temporal dependencies in electricity consumption data [9]. ARIMA models have also proven valuable in the field of public health, particularly in predicting the spread of infectious diseases. Kumar and Patel (2023) used ARIMA to model the spread of COVID-19 in various regions. Their findings indicated that ARIMA models could effectively forecast short-term trends in infection rates, providing valuable insights for public health officials to allocate resources and implement timely interventions [10]. Environmental science is another domain where ARIMA models have been effectively employed. For instance, a study by Johnson et al. (2022) utilized ARIMA models to predict air quality indices in urban areas. The research demonstrated that ARIMA models could accurately forecast pollutant levels, which is critical for informing public health advisories and environmental policies [11]. In the retail sector, ARIMA models are extensively used for demand forecasting, which helps businesses manage inventory more efficiently [12]. A recent study by Liu and Chen (2023) examined the use of ARIMA in forecasting seasonal product demand, such as ice cream sales. The study found that ARIMA models, by effectively accounting for seasonality and trends, provided reliable forecasts that aided in optimizing stock levels and reducing wastage [13]. Comparative analyses have also been conducted to evaluate the performance of ARIMA models against other advanced forecasting techniques. Zhang et al. (2023) conducted a comprehensive review comparing ARIMA with machine learning models, including neural networks and support vector machines. The review concluded that while machine learning models could offer competitive performance, ARIMA remained a preferred choice for many applications due to its simplicity, interpretability, and strong performance in scenarios with well-defined temporal patterns [14].



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METHODOLOGY

The ARIMA method consists of four key steps: Identification: Establish whether the time series exhibits stationarity; if not, ascertain the number of differences required to render it stationary. Create differenced data to use in diagnostic plots. Identify the ARIMA model parameters using auto-correlation and partial auto-correlation functions. Estimation: Train the model by estimating the parameters (coefficients) using the available data. Diagnostic Checking: Assess the fitted model against the data to identify areas for improvement. This step involves checking for overfitting and analyzing residual errors. Forecasting: Use the validated model to forecast future values of the time series.

RESULTS AND DISCUSSION

This study delves into forecasting demand for the final product in food manufacturing setting by leveraging real-world data, examining the precision and attributes of these predictions. The research assesses the efficacy of demand forecasting in the food manufacturing sector [15]. Utilizing the Box-Jenkins methodology, our study is divided into four stages: identification, estimation, diagnostic checking, and forecasting. The depicted model in Figure 1 utilizes demand data for the final product obtained from a Moroccan food manufacturing company, covering the period from January 2018 to December 2023.

Identification of model

During this phase, we initiate the preprocessing of the data to ensure stationarity and then determine initial values for p and q , which may be refined during model fitting. To confirm the data's adherence to a stationary process, we conduct the Dickey-Fuller unit root test for stationarity.

H_0 : The series has a unit root.

H_1 : The series does not have a unit root and is stationary.

Since the calculated p-value is greater than the threshold significance level $\alpha = 0.05$, we cannot reject the null hypothesis. The risk of rejecting the null hypothesis when it is actually true is 84.38%. After confirming the stationarity of the series, we observe from the ACF and PACF correlograms that our model is neither purely autoregressive (AR) nor purely moving average (MA). Consequently, we tested several models to determine the most suitable one for forecasting sales.

Estimation of model's coefficients

The ARIMA procedure within the SPSS Time Series module enables us to estimate model coefficients by defining parameters p , q , and d through a rapid maximum likelihood estimation algorithm. This process produces new time series that depict adjusted or predicted values according to the model, residuals (errors in adjustment), and 95% confidence intervals for these adjustments. The preferred model is the most straightforward, aiming to minimize certain criteria, such as AIC, SBC, variance, and maximum likelihood. The chosen model is ARIMA (0, 1, 1). In the case of alternative models, the student "T-RATIO" test values either fall within the ± 1.96 range, or one of the criterion values for minimization exceeds those observed for the ARIMA (1, 0, 1) model with a constant value.

Accuracy of ARIMA (1, 0, 1) model

The model accuracy was evaluated by juxtaposing actual sales data with simulated sales for the corresponding period. As depicted in Figure 2, this comparison indicates that the chosen model demonstrates remarkable precision and adeptly replicates the dynamic sales patterns. Consequently, this model proves to be well-suited for demand analysis and forecasting within the context of food manufacturing. The graph confirms the model's validity, as the predicted demand closely follows the actual data, fluctuating within the upper and lower confidence limits.





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Although the error varies, it remains within an acceptable tolerance range. To further reduce this error, we propose a new approach for future work.

Forecast

Following the selection of the optimal demand model, we conducted forecasting using IBM SPSS Forecasting. Table 1 and Figure 3 showcase the sales projections derived from implementing our ARIMA (1, 0, 1) model for the upcoming 10 months, spanning January 2024 to October 2024. The outcomes distinctly demonstrate the efficacy of the chosen model in both modeling and predicting future demand within this food manufacturing setting. However, it is crucial to continuously update the historical data with new information to refine and enhance the model and its forecasts. The forecasts obtained from the model facilitated production decision-making within the food company. Specifically, the model allowed for accurate demand predictions, making production planning clearer and more efficient, thereby reducing significant cost losses. This improved forecasting aids in making informed decisions related to raw material supply and daily production schedules, ultimately enhancing the entire production process and minimizing any potential losses.

CONCLUSION

Forecasting demand holds paramount importance in supply chain management and the seamless integration of diverse business operations, rendering it a pivotal planning process crucial for a company's future prosperity. Within this study, we constructed an ARIMA model to predict demand for the final product within a food manufacturing environment, employing the Box-Jenkins time series methodology. Multiple models were derived from historical demand data, with the optimal selection based on four key performance metrics: SBC, AIC, standard error, and maximum likelihood. The ARIMA (1, 0, 1) model emerged as the most fitting choice, as it minimized all four criteria effectively. The results demonstrate that this model effectively models and forecasts future demand in the food manufacturing industry, providing managers with reliable guidelines for decision-making. In forthcoming endeavours, our intention is to expand upon our methodologies by integrating qualitative and quantitative techniques, thereby enhancing the reliability and precision of our forecasts. We also aim to investigate the neural network approach and compare its outcomes with those derived from the ARIMA model, with the goal of validating the efficacy of artificial neural networks (ANNs) within the food industry. Furthermore, we will explore the potential of combining ARIMA with radial basis function (RBF) models to further elevate the level of accuracy achievable.

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Table 1. Forecast sales from January 2024 to October 2024

Year-24	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Forecast	81	84	86	89	92	95	98	100	102	103
UCL	154	156	158	161	162	162	163	164	164	165
LCL	52	54	55	57	57	58	58	59	59	60

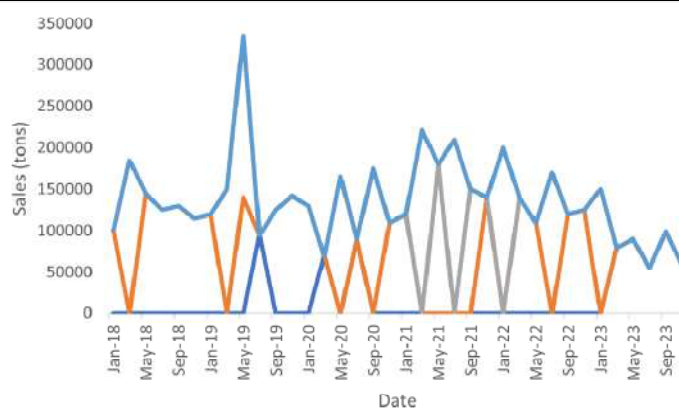


Figure 1. Trends in sales of the final product over time





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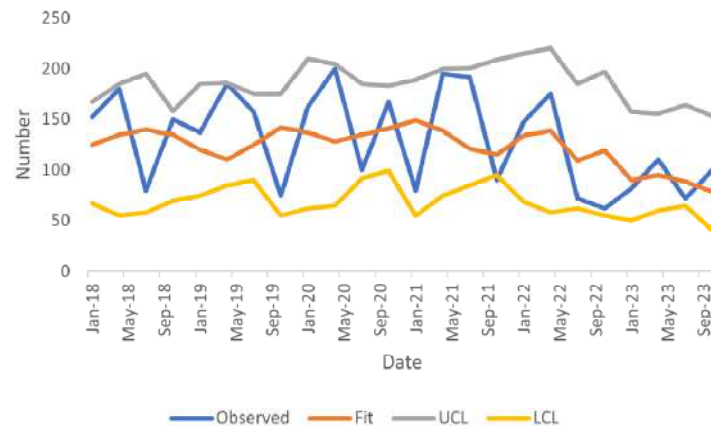


Figure 2. The experimental and the simulated sales

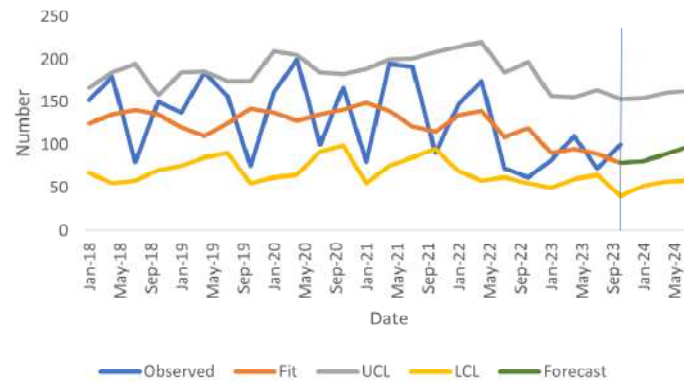


Figure 3. The experimental and the simulated sales with forecast





RESEARCH ARTICLE

Restoring Cervical Health : An Ayurvedic Perspective on Cervical Erosion

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ABSTRACT

Cervical erosion accounts for a substantial percentage (60–80%) of the many gynaecological issues in daily practice, especially in developing countries where adequate focus is not given on nutrition & hygiene. Cervical erosion, also referred as cervical ectropion, is a benign gynaecological condition characterized by the replacement of the squamous epithelium of the ectocervix with columnar epithelium, typically from the endocervical canal. It is often influenced by hormonal fluctuations, mechanical trauma, or chronic cervicitis. It is commonly asymptomatic, though it may present with vaginal discharge or post-coital bleeding. Cervical erosion is not directly associated with any disease mentioned in Ayurvedic classics; nonetheless, *Garbhasaya Greevagata Vrana* is the closest approximation. A 36-year-old female patient with complaints of back pain and profuse vaginal discharge since ten months approached to the OPD. Over the course of one month, she received a combination of treatment with unique Ayurvedic approach where *Shamana Chikitsa* as oral medications and *Sthanik Chikitsa* - local procedures with Apamarga Kshara, Jatyadi Taila etc. were provided. After treatment, noticeable improvement was observed.

Keywords: Apamarga Kshara, Cervical erosion, Garbhasaya Greevagata Vrana, Jatyadi Taila, Sthanik Chikitsa.





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INTRODUCTION

Cervical erosion is the condition where the squamous epithelium of the portio vaginalis around the external os is invaded by the cervical canal's columnar epithelium. Although excessive ovarian hormone production is the prime cause [1]. Some other factors also play pivot role, which are - mechanical traumas, iatrogenic causes such as procedures like cervical dilatation, insertion of intra uterine devices, or surgical interventions [2], Persistent infections such as Chlamydia trachomatis, Neisseria gonorrhoeae, or HPV infection, Tuberculosis or syphilis affecting the cervix [3], Chemical or Physical Irritants, Congenital Factors, Neoplastic Conditions [4]. While modern medical approaches rely on surgical and para-surgical interventions, Ayurveda offers a holistic approach emphasizing internal and external therapies, herbal formulations, and lifestyle modifications to promote healing and restore the normal structure and function of the cervix [5]. Classical texts like *Sushruta Samhita* and *Ashtanga Hridaya* elaborate on various *Vrana Ropana* (Healing) principles by utilizing *Kashaya* (decoction), *Taila* (medicated oils), and *Kshara* (medicated alkali application) to address tissue damage and inflammation [6,7]. This article presents a case study highlighting the efficacy of Ayurvedic management in cervical erosion through a personalized treatment approach. The focus was on the integration of *Sthanika Chikitsa* (local procedures) and *Shamana Chikitsa* (oral medications) to accelerate the replacement of cells in their original form, alleviate the symptoms, and prevent recurrence [8,9].

CASE REPORT

A 36-years-old married woman approached the *Prasuti Tantra Evum Stree Roga* – Ayurveda Gynaecology and Obstetrics OPD at Parul Ayurved Hospital - Vadodara, Gujarat with the chief complaint of having profuse vaginal discharge and severe backache since last 10 months. On first visit, following observations were recorded.

Past Medical History: Nothing specific

Past Surgical History: D & C – 13 Years Ago

Menstrual History

Duration: 2-3 days

Interval: 30 days

Regular | Painful + | Foul Smell + | No clots | 2 pads/day

Obstetric History: G3/P2/A1/L1/D1

A1: 13 Years Ago | at 3 Months of Gestation | Spontaneous Abortion | D & C

P1L1: 12 years | Male Child | FTND @ Hospital

P2D1: 9 Years Ago | At the age of 1.5 Years | Due to Scorpion bite **Medical History:**

No H/O HTN, D.M., or any systemic illness.

Family History: Not significant

Occupational History: Housewife.

Personal History:

Appetite – Moderate.

Diet – Veg (Irregular timing of meals).

Sleep – Disturbed.

Urine – Regular (5-6 times/day; 1 time/night - occasionally) Bowel – Regular, satisfactory. No H/O Constipation.

Addiction – No Any

On Examination

Temperature: Afebrile on Palpation.

Pulse Rate: 86bpm

Blood Pressure: 110/70 mmHg

Systemic Examination





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Respiratory System: B/L air entry clear. NAD
 Cardiovascular System: S1S2 heard normal. NAD
 Central Nervous System: Patient was conscious and oriented. NAD P/A: Soft, non-tender.
 P/S: Cx - Bulky, Oedematous
 Congestion ++
 Erosion ++
 Vaginal discharge +++
 P/V: Uterus NS | AV/AF | FF
 CMT +
 Cx – High Above

Investigations

- Vaginal Swab Culture & Sensitivity: No Growth
- Cytology: Negative for Intraepithelial Lesion or Malignancy • USG Abdomen & Pelvis:
 - Normal Anteverted Uterus (8.4 * 3.6 * 4 cm).
 - Myometrium appears homogeneous with no evidence of Focal Lesion. -Endometrial Lining is Central and Normal in thickness.
 - E.T. 5.2 mm.
 - B/L Ovaries: Normal
 - Hepatomegaly with Fatty Liver Grade 1.
 - Urine Routine & Micro: WNL
 - Hb: 12.4 gm%
- RBS: 89mg/dl

Samprapti Ghataka

Dosha: Vata Kapha

Dushya: Rasa, Rakta, Mamsa

Srotasa: Rasavaha, Raktavaha, Mamsavaha, Aartavavaha

Agni: Jatharagni & Dhatvagni Mandya

Srotodushiti: Atipravritti, Sira Granthi

Udbhava Sthana: Aamashaya, Pachyamanashaya

Vyakti Sthana: Garbhashaya Mukha

Roga Marga: Madhyama

Treatment Protocol

1. *Yoni Dhavana* – Triphala Kashaya – once in a day up to 7 days.
2. *Apamarga Kshara Pratisarana* once in a day up to 7 days.
3. *Yoni Pichu* – *Jatyadi Taila* – once in a day up to 7 days.
4. *Tab. Pradarantak Rasa* 1 tab twice a day after meal with *Tandulodaka* up to 15 days. (1 Tab – 125 mg)
5. *Tab. Triphala Guggulu* 1 tab thrice a day after meal with warm water up to 1 month.
6. *Tab Chandraprabhavati* 2 tab twice a day after meal with warm waater up to 1 month.

Pathya-Apathya

Pathya: Drink warm Jeera water, Buttermilk, and green gram water, maintain personal hygiene, and avoid common toilets.

Apathya: Curd, Sour items, Rice, White flour, Chickpea flour, oily food items, salty food, etc.





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RESULTS AND DISCUSSION

The Ayurvedic management of cervical erosion emphasizes addressing the root cause through a comprehensive approach that includes both systemic and local treatments. This case study explores the efficacy of Ayurvedic formulations and therapeutic procedures in promoting tissue repair and restoring cervical health. The results emphasise the significance of a personalized treatment strategy based on the evaluation of *Samprapti* (pathogenesis) and *Dosha* imbalances.

Effects of *Triphala Kwatha Yoni Prakshalana*

Triphala Kwatha can be effective in cervical erosion by its *Sodhana* (Purifying), *Ropana* (Healing), *Vedana Samaka* (Pain Relieving) and *Rasayana* (Rejuvenating) Properties. It is *Tridosha Samaka* (*Vata*, *Pitta*, *Kapha* Pacifying). It also exhibits *Sangrahi* (Astringent Property) and *Lekhana* (Scraping) properties which are essential for healing the *Vrana*. [10] By *Ropana* property it promotes the growth of healthy tissues at the place of displaced tissue, which helps in correction of cervical erosion. Chronic inflammation is deleterious and affects most major chronic health conditions. *Triphala* has shown promise as an anti-inflammatory agent. In one study, *Triphala* performed better or equivalent when compared with standard drug treatment for a variety of biochemical measurements of inflammation.[11] In addition, *Triphala* significantly reduced inflammatory markers as well as bone and cartilage degradation in arthritic rats. [12] *Triphala* reduces the expression of inflammatory mediators such as IL-17 (interleukin), COX-2 (cyclooxygenase), and RANKL (receptor activator of nuclear factor kappa-B ligand) through inhibition of NF- κ B (nuclear factor kappa B) activation. Another study found that *Triphala* increased antioxidant levels and decreased lipid peroxidation in the tissues of arthritic rats.[13] In lipopolysaccharide-stimulated macrophages, *Triphala* treatment suppressed the production of inflammatory mediators such as TNF α (tumor necrosis factor alpha), IL-1 β , IL-6, MCP-1 (Monocyte Chemoattractant Protein-1), VEGF (vascular endothelial growth factor), NO (nitric oxide), and PGE2 (Prostaglandin E2), intracellular free radicals, inflammatory enzymes (such as iNOS (inducible nitric oxide synthase) and COX-2), and lysosomal enzyme release.[14] Chebulagic acid, a constituent in *Triphala*, was found to inhibit COX and 5-LOX (5-lipoxygenase), which are both major enzymes involved in inflammation and carcinogenesis.[15]

Effects of *Apamarga Kshara Pratisarana*

Apamarga Kshar acts as *Ksharana* (Corrosive) [16], *Ropana* (Healing) [17], *Lekhana* (Scraping) [18], *Shodhana* (Purification) [16]. Its unique ability to remove unhealthy tissue and promote healing makes it a valuable intervention in cervical erosion. The ethanolic extract of *Apamarga* (*Achyranthes aspera*) exhibits significant anti-inflammatory activity by inhibiting pro-inflammatory cytokines as IL-6 and TNF- α . [19] Methanolic extracts of *Achyranthes aspera* have shown free radical scavenging activity, attributed to its phenolic and flavonoid content. [20] *Apamarga* enhances epithelialization, attributed to its high glycoside and saponin content. [21] This is how *Apamarga Kshara* works being effective in cervical erosion.

Effects of *Jatyadi Taila Yoni Pichu*

Jatyadi Taila balances *Pitta* and *Kapha Doshas*, promotes *Ropana* (healing), and acts as a *Shodhana* (cleansing) agent for the vaginal mucosa. Its *Snigdha* (unctuous) and *Sheetala* (cooling) properties reduce inflammation, alleviate burning sensation, and aid tissue regeneration.[22] It's Analgesic, cooling [23], Anti-Microbial, and Anti-Inflammatory [24] effects help reversing the pathogenesis. **Pradarantaka Rasa** contains *Shuddha Parada* (Purified Mercury), *Shuddha Gandhaka* (Purified Sulfur), *Abhraka Bhasma* (Calx of Mica), *Tamra Bhasma* (Calx of Copper), *Shuddha Hingula* (Purified Cinnabar), *Kukutaandatvak Bhasma* (Calx of Hen's Eggshell), *Nagavalli Swarasa* (Juice of Betel Leaf). These drugs are having *Tridoshaghna* (*Vata*, *Pitta*, *Kapha* pacifying property), *Rasayana* (Rejuvenating), *Shothahara* (Anti-Inflammatory property) with *Pradarnashak* (discharge pacifying) property. *Kashaya* (Astringent) and *Tikta Rasa* (Bitter Taste) help in the reduction of vaginal discharge.[25,26] Ingredients of *Pradarantaka Rasa* are Anti Inflammatory [27], Antimicrobial [28], Tissue Regeneration and Healing [29] and Anti-Oxidant [30] Activities, helps in restoring normalcy of cervical erosion.





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Triphala Guggulu has *Daha Shamana* (Reduce Burning), *Vedanahara* (Pain Relieving), *Vrana Sodhana* (Wound Purifying) and *Ropana* (Healing) Properties. So, it is useful in the treatment of erosion. Additionally, *Triphala Guggulu* has been shown to have anti-inflammatory, anti-oxidant, and wound-healing qualities. [31,32,33] **Chandraprabha Vati** is a *Guggulu Kalpana Kharaliya Rasayana* which acts as *Rasayana* (rejuvenator), *Srotoshodhaka* (cleaner of channels), and *Vedanasthapaka* (analgesic) also.[34] Its ingredients also have Anti-Inflammatory [35], Anti-Microbial [36], and Astringent and Haemostatic [37] properties which are core in the management of erosion. Combining systemic medicines and local procedures is a successful Ayurvedic therapy strategy for cervical erosion. Using formulations like *Triphala Guggulu*, *Chandraprabha Vati*, etc. and local procedures like *Yoni Prakshalana* (vaginal wash), *Kshara Pratisarana* (medicated alkali) & *Yoni Pichu* (medicated tampon) aid in the healing process and lessen inflammation. In addition to dietary support and lifestyle changes improve tissue repair, fortify reproductive health, and stop recurrence.

CONCLUSION

A comprehensive strategy is necessary for the optimal therapy and restoration of cervical health in cases of cervical erosion. By combining internal medications, local treatments like *Yoni Dhavana* (Vaginal Douch), *Kshara Pratisarana* (Medicated Alkali Application) and *Yoni Pichu* (Vaginal Swab) as well as lifestyle changes, Ayurveda, with its tried-and-true principles and therapeutic methods, provides hopeful solutions. In addition to nutritional and behavioral advice, formulas such as *Pradarantaka Rasa*, *Triphala Guggulu*, and *Chandra Prabha Vati* combinedly provide a comprehensive approach to the problem by addressing its underlying cause, reducing symptoms, and encouraging tissue replacement to its normal state.

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Table:1 General Examination

<p><u>Ashtavidha Pariksha:</u> 1. NADI: Kapha Pradhana Pitta Anubandhi 2. MALA: Samyaka Frequency: 1 time / 24 hrs. 3. MUTRA: Samyaka Frequency: 5-6 times/day; 1 time/night (occasionally) 4. JIHVA: Saama 5. SHABDA: Spashta 6. SPARSHA: Anushnasheeta 7. DRIK: Prakruta 8. AAKRITI: Madhyam</p>	<p><u>Dashavidha Pariksha:</u> DEHABALA PARIKSHAN: 1. Prakriti: KaphaPittaja 2. Vikruti: Tridosha 3. Sara: Meda Sara 4. Samhanana: Madhyama 5. Satva: Madhyama 6. Satmya: Madhyama 7. Ahara Shakti: Abhyavarana Shakti: Madhyama Jarana Shakti: Madhyama 8. Vyayama Shakti: Avara 9. Vaya: Madhyama 10. Pramana: Madhyama Ht: 156 cm Wt: 60 kg 11. Bala: Madhyama 12. Koshtha: Madhyama 13. Agni: Vishama</p>
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Table 2. Observation and Results

DAY	Vaginal Discharge	Erosion	Congestion	Backache
0	+++	++	++	+++
07 th	++	++ (colour changed from bright red to light red)	++	+++
15 th	+	+	+	+
30 th	Absent	Absent	Absent	Absent





Groundwater Pollution in West Bengal: Challenges and Solutions to Arsenic Contamination

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ABSTRACT

Arsenic toxicity poses a significant threat in West Bengal, India. Nearly half of the state in India is affected by this hazardous metal. Geological studies have identified the layers and conditions contributing to arsenic contamination in the lower Gangetic delta. Prolonged exposure to arsenic has led to various health issues, including skin disorders, respiratory problems, cardiovascular diseases, and hematological conditions. Additionally, chronic exposure has been linked to diabetes, genetic damage, and cancer-related complications. This study examines the current status of arsenic contamination, the geological framework of the region, and the physiological and biochemical impacts of prolonged arsenic exposure on human health.

Keywords: Geological studies have identified the layers and conditions contributing to arsenic contamination in the lower Gangetic delta.

INTRODUCTION

Groundwater pollution, particularly arsenic contamination, has become a serious environmental and health crisis in West Bengal, India. Arsenic contamination in the state is primarily associated with geological formations in the lower Gangetic delta, where naturally occurring arsenic deposits leach into groundwater sources (Ghosh &Kanchan, 2011). The problem is exacerbated by human activities, such as excessive groundwater extraction for irrigation and drinking purposes, which mobilize arsenic from sediments into the water supply (Farooq *et al.*, 2010). Districts like Murshidabad and Nadia are among the most affected, with several blocks showing arsenic levels well above the World Health Organization's permissible limit of 10 µg/L (IOSR Journals, 2013).The health impacts of arsenic exposure in these regions are significant and widespread. Long-term ingestion of arsenic-contaminated water has

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been linked to skin disorders, respiratory issues, cardiovascular diseases, and hematological conditions. Additionally, chronic exposure increases the risk of serious conditions such as diabetes, genetic damage, and cancers, including skin, bladder, and lung cancers (Stüben *et al.*, 2003). Affected communities, particularly in rural areas, often lack access to adequate healthcare, making the detection and treatment of arsenicosis—chronic arsenic poisoning—a challenge (IOSR Journals, 2013). Addressing this issue requires a multi-faceted approach that integrates scientific, legal, and community-based interventions. On the scientific front, studies suggest that deeper aquifers are less prone to contamination, indicating that shifting water extraction from shallow to deeper sources could mitigate risks (Stüben *et al.*, 2003). Legal interventions are equally critical. Although the Indian government has implemented various policies to regulate groundwater use and monitor water quality, enforcement remains weak in many regions. Public awareness campaigns and community participation are essential to ensure that individuals understand the risks associated with contaminated water and adopt safe practices, such as using arsenic filtration systems and rainwater harvesting (Ghosh & Kanchan, 2011). This study aims to provide an overview of the extent and impact of arsenic contamination in West Bengal's groundwater, focusing on the challenges that hinder effective mitigation. It also examines existing solutions, including technological innovations and policy frameworks, and explores sustainable strategies for long-term water management. By analyzing the interplay of natural processes, human activities, and policy responses, the study seeks to offer actionable insights into combating arsenic contamination and safeguarding public health in the region.

MATERIALS AND METHOD

The methodology for the work has been structured to ensure inclusive data collection, analysis, and interpretation. This methodology encompasses various phases, including literature review, field study, data collection, analysis etc. To assess the current state of groundwater quality in various regions of West Bengal researcher Selected multiple sites across arsenic-affected districts, including Murshidabad, Nadia, and Malda. Researcher tested water samples for arsenic levels. Mostly the researcher depends on secondary data. The researcher has conducted surveys using questionnaires to gather information on health effects experienced by individuals consuming contaminated water. Focus on skin disorders, respiratory issues, and gastrointestinal problems.

RESULT AND DISCUSSION

The stratigraphic assessment of arsenic-prone aquifer zones in southern West Bengal indicates that these aquifers lie beneath the alluvial plains (Ghosh & Kanchan, 2011). The Young Delta Plain (YDP) consists of a soil layer measuring 1 to 2 meters in thickness, capped with soft iron-manganese concretions up to 0.2 meters thick, and underlain by calcrete deposits (Farooq *et al.*, 2010). In this region of the Bengal Basin, particularly around the Bhagirathi River, distinct morphostratigraphic units have been identified in the subsurface; however, deeper layers of the YDP remain poorly exposed (Stüben *et al.*, 2003). Identifying the Quaternary section has proven challenging, yet borehole data from the western Gangetic plains primarily reveal sequences of clay and sand that formed in saline conditions and contain microfossils dating back to the Upper Pliocene epoch (Stüben *et al.*, 2003). Notably, the Toba-ash bed marker, dating back approximately 75,000 years, has been identified in the lower parts of the Quaternary profiles of the Brahmani and Barakar River regions, situated just west of the Ganga-Brahmaputra basin margin (Ghosh & Kanchan, 2011). Arsenic-bearing aquifers are found within the Holocene sediments located beneath the YDP. These contaminated sediments have partially extended into the Barind region, which lies north of the Ganges channel, particularly affecting areas such as the Malda district (Table 1). The valleys of the Holocene are filled with silt and clay, which have been deposited in deeply eroded and incised Pleistocene Barind sediments (Table 2) (Stüben *et al.*, 2003). Based on lithological analyses from groundwater drilling and the examination of heavy mineral content, districts in West Bengal impacted by arsenic contamination have been categorized into three stratigraphic zones, determined by the subsurface sediment characteristics beneath the Young Delta Plain in both northern and southern parts of the state (Ghosh & Kanchan, 2011; Farooq *et al.*, 2010).



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The stratigraphic assessment of aquifer zones vulnerable to arsenic contamination in southern West Bengal shows that these aquifers are situated beneath the alluvial plains. The Young Delta Plain (YDP) is characterized by a soil layer that ranges from 1 to 2 meters in thickness, capped with soft iron-manganese concretions up to 0.2 meters thick and underlain by calcrete deposits. In the Bengal Basin, especially near the Bhagirathi River, various morphostratigraphic units have been identified in the subsurface, although deeper layers of the YDP remain largely hidden. Identifying the Quaternary section has posed challenges, as borehole investigations primarily reveal a sequence of clay and sand deposits formed in saline environments, which contain microfossils that date back to the Upper Pliocene Cebrian, M. E., Albores, A., Aguilar, M., *et al.* (1983). A significant marker, the Toba-ash bed, estimated to be about 75,000 years old, has been found in the lower portions of the Quaternary profiles of the Brahmani and Barakar River regions, located just west of the Ganga-Brahmaputra basin margin Acharyya, S. K., Lahiri, S., Raymahashay, B. C., *et al.* (1999). The Holocene sediments situated beneath the YDP harbor arsenic-laden aquifers, and these contaminated sediments have encroached into the Barind area, particularly affecting the Malda district, which lies to the north of the Ganges channel Das, A. (2015). The valleys formed during the Holocene period are filled with silt and clay, which have been deposited in deeply eroded and incised sediments from the Pleistocene Barind (Table 2). Through lithological analyses from groundwater drilling and assessments of heavy mineral content, the arsenic-impacted districts in West Bengal have been divided into three stratigraphic zones based on the characteristics of subsurface sediments located beneath the YDP across both northern and southern regions of the state Hotta, N. (1989).

Effect and Challenges to Arsenic Pollution**Skin Diseases**

Chronic arsenic exposure from contaminated drinking water leads to significant skin conditions, notably pigmentation and keratosis. A population-based survey in West Bengal, which included 4,093 females and 3,590 males exposed to arsenic, indicated that men experienced two to three times more severe skin issues than women. In addition to skin lesions, chronic arsenic toxicity results in various systemic health problems (Adhikary & Mandal, 2017, p. 106).

Respiratory Diseases

Long-term consumption of arsenic-laden water (800 mg/L) has been linked to non-malignant lung diseases. Approximately 38% of those exposed reported chronic cough, compared to just 3.1% among the unexposed. Furthermore, chronic lung diseases were prevalent in 57% of individuals suffering from arsenic toxicity (Adhikary & Mandal, 2017, p. 106).

Gastrointestinal Disorders

Dyspepsia emerges as the most common gastrointestinal symptom, affecting 38.4% of those chronically exposed to arsenic. Additionally, gastroenteritis has been attributed to drinking water with arsenic concentrations exceeding 50 mg/L. (Adhikary & Mandal, 2017, p. 106)

Nervous System Diseases

Chronic arsenic exposure can lead to peripheral neuropathy, with 47.4% of affected individuals experiencing symptoms like tingling, numbness, and limb weakness. Reports indicate a heightened incidence of cerebrovascular diseases and other neurological complications, including sleep disturbances and cognitive impairments. (Adhikary & Mandal, 2017, p. 106)

Cardiovascular Issues

A significant complication of chronic arsenic exposure is Blackfoot disease (BFD), affecting about 8.9% of the population in contaminated areas. Other vascular disorders, such as Raynaud's syndrome and acrocyanosis, have also been noted. Furthermore, arsenic exposure correlates with a 6.2% increase in hypertension prevalence in West Bengal.



**Paramita Bhattacharyya****Hematological Effects**

Both acute and chronic arsenic poisoning result in hematological issues like anemia, leucopenia, and thrombocytopenia. In West Bengal, around 50% of individuals exposed to arsenic-contaminated groundwater (200-2,000 mg/L) suffer from anemia. (Adhikary & Mandal, 2017, p. 106)

Diabetes

A dose-response relationship exists between cumulative arsenic exposure and the prevalence of diabetes mellitus, particularly in arsenic-endemic regions. Although significant increases in diabetes prevalence have been reported in Bangladesh, similar data for West Bengal is lacking. (Adhikary & Mandal, 2017, p. 106)

Arsenicosis and Cancer

Arsenic exposure significantly increases cancer risk, particularly for skin, urinary bladder, and lung cancers. In arsenic-affected villages in West Bengal, rates of skin cancer were recorded at 4.35%, with 0.78% for internal cancers. (Adhikary & Mandal, 2017, p. 106)

Genotoxic Effects

Prolonged arsenic exposure through drinking water is associated with genotoxic effects, including heightened chromosomal aberrations and increased formation of micronuclei in buccal and urothelial cells. In West Bengal, the frequency of micronuclei formation in peripheral lymphocytes, oral mucosa, and urothelial cells was nearly five times higher in exposed individuals compared to those unexposed. Monsur, M. H. (1995).

Addressing groundwater pollution and arsenic contamination in West Bengal involves several legal provisions and frameworks, including:

Water (Prevention and Control of Pollution) Act, 1974

This act establishes the Central and State Pollution Control Boards for the regulation and management of water quality, including the prevention of groundwater contamination.

Environment Protection Act, 1986

This law provides a framework for the protection and improvement of the environment, including regulations on hazardous substances and waste management that can affect groundwater quality.

Public Health Act, 1939

This act allows for the regulation of drinking water quality to prevent health hazards due to contaminated water supplies.

Right to Information Act, 2005

This act enables citizens to seek information regarding the quality of water and the efforts made by authorities to manage arsenic contamination. The Supreme Court of India has provided significant guidelines regarding groundwater pollution, particularly concerning arsenic contamination, through various landmark cases, notably the case of *M.C. Mehta vs. Union of India* (1996). In this case, the Court recognized the severe depletion of groundwater resources across the country and stressed the need for stringent regulation of groundwater extraction to mitigate pollution and protect public health.

CONCLUSIONS

Chronic arsenic poisoning from consuming groundwater contaminated with arsenic poses a significant health risk globally. It can lead to alarming health issues, including skin, liver, cardiovascular, respiratory, and gastrointestinal disorders, particularly concerning in today's fast-paced lifestyle. Furthermore, exposure may result in neurological problems and genotoxicity, which can cause severe genetic mutations. Geological and stratigraphic analyses indicate



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that the Ganga-Brahmaputra delta is particularly vulnerable due to the shallow nature of its lithological layers, heightening the urgency for effective interventions.

Legal Challenges

- Existing laws such as the Water (Prevention and Control of Pollution) Act, 1974 and the Environment Protection Act, 1986 may lack specific provisions for groundwater protection, leading to ineffective management of arsenic contamination.
- The Pollution Control Boards may face challenges in enforcing penalties due to bureaucratic hurdles and lack of resources, allowing violators to escape legal consequences.
- Inadequate monitoring of groundwater quality and lack of transparency in reporting hinder legal actions against polluters.
- Under the Right to Information Act, 2005, while communities can seek information, there is often insufficient awareness on how to effectively utilize this right for groundwater protection.
- Determining liability under existing laws can be difficult, particularly when pollution sources are diffuse, as seen in agricultural runoff.

Suggestions

- Revise the Water (Prevention and Control of Pollution) Act to include specific provisions for groundwater quality monitoring and standards, especially concerning arsenic levels.
- Empower the West Bengal Pollution Control Board with more resources and authority to enforce environmental regulations effectively.
- Implement a robust groundwater monitoring system under the National Water Policy, 2012, ensuring regular testing for arsenic and other contaminants.
- Conduct outreach programs to educate communities on their rights under the Right to Information Act and how to report violations effectively.
- Establish legal aid clinics focusing on environmental law to assist affected communities in filing claims and navigating legal processes related to groundwater pollution.
- Work with non-governmental organizations to develop community-led monitoring programs and awareness campaigns regarding arsenic contamination.
- Allocate funds for research on innovative water purification technologies under the Ministry of Environment, Forest and Climate Change, focusing on arsenic removal methods.
- Encourage the adoption of sustainable farming practices that reduce chemical runoff, supported by state and central government schemes.

By addressing these legal challenges and implementing targeted solutions, West Bengal can enhance its efforts to combat groundwater pollution and protect public health.

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Table.1: Affected areas of Arsenic in West Bengal

Year	Affected Districts	Affected Blocks	Affected Villages	Affected Municipalities
1993	7	34	78	3
1995	7	56	388	9
1997	8	61	1302	9
1998	8	65	1312	9
1999	8	67	1550	11
2001	8	75	2065	11
2002	8	75	2579	11

Source: Adhikary R, Mandal V. Status of arsenic toxicity in ground water in west bengal, india: a review. *MOJ Toxicol*. 2017;3(5):104–108. DOI: 10.15406/mojt.2017.03.00063



**Paramita Bhattacharyya****Table.2: Highly Contaminated Districts of West Bengal**

Highly Contaminated Districts	Permissible Limit	Arsenic Concentration
South 24 Parganas	0.05 mg/L	0.06 - 3.20 (mg/L)
North 24 Parganas	0.06 mg/L	0.06 - 1.28 (mg/L)
Maldah	0.05 mg/L	0.05 - 1.434 (mg/L)
Nadia	0.05 mg/L	0.05 - 1.00 (mg/L)
Murshidabad	0.05 mg/L	0.05 - 0.90(mg/L)
Burdwan	0.10 mg/L	0.10 - 0.50 (mg/L)
Howrah	0.09 mg/L	0.09 (mg/L)
Hooghly	0.06 mg/L	0.6 (mg/L)

Source: Adhikary R, Mandal V. Status of arsenic toxicity in ground water in west bengal, india: a review. MOJ Toxicol. 2017;3(5):104–108. DOI: 10.15406/mojt.2017.03.00063





RESEARCH ARTICLE

Analytical Method Development and Validation by High Performance Liquid Chromatography (HPLC)

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ABSTRACT

The evolution of analytical methods in pharmaceuticals is crucial due to regulatory requirements. The identification of an Active Pharmaceutical Ingredient and excipients can only be achieved when the testing method is validated according to ICH, WHO guidelines or GMP standards. The reliability of evolution hinges on the adherence to an accurate and precise strategy. This discussion focuses on the systematic method development techniques and validation parameters. High Performance Liquid Chromatography (HPLC) is a method employed to separate components from a mixture. This technique involves two phases; the stationary phase and the mobile phase. The separation of components relies on variations in partition coefficient between the stationary and mobile phase. This review article emphasizes the development and validation of methods by using HPLC. It plays an important role in the discovery, development, manufacturing of pharmaceutical drugs and various other studies related to plants and animals. An analytical method is established to evaluate a key characteristic of products or drug substance in relation to predefined acceptance criteria. The validation of HPLC method, in accordance with ICH guidelines, encompasses all performance characteristics required for validation, including specificity, accuracy, precision, range, linearity, limit of detection, limit of quantification, robustness and system suitability testing.

Keywords: Chromatography, validation, Accuracy, Linearity, Robustness.





INTRODUCTION

High-Performance Liquid Chromatography (HPLC) technique which enables the separation of components by distributing them between two immiscible phases; a mobile phase and a stationary phase. It has become one of the most effective tools in analytical chemistry, capable of separating, identifying, and quantifying compounds in any liquid-soluble sample. It is recognized as the most precise analytical method commonly employed for both the quantitative and qualitative analysis of pharmaceutical products.(1). HPLC is advanced type of column chromatography. Unlike traditional chromatography, where the solvent typically flows through the column by gravity. HPLC utilize high pressure up to 400 atmospheres to propel the solvent. This technique allows for the effective separation of sample components based on their varying affinities. In High-Performance Liquid Chromatography (HPLC), pumps are used to deliver a pressurized liquid solvent that contains the sample mixture into a column packed with solid adsorbent material. Each component of the sample interacts differently with the adsorbent, resulting in varying flow rates for each substance. This variation in flow rates allows for the separation of the components as they move through the column. In essence, chromatography can be viewed as a mass exchange process that involves adsorption.(2) High-Performance Liquid Chromatography (HPLC) comprises several essential components: a column filled with a stationary phase, a pump that drives the mobile phase through the column, and a detector that records the retention times of various molecules. The retention time is affected by the interactions between the stationary phase, the analytes under examination, and the solvents utilized. When samples are introduced in small quantities into the mobile phase stream, they undergo different levels of retardation due to specific chemical or physical interactions with the stationary phase. This retardation is influenced by both the properties of the analyte and the compositions of the stationary and mobile phases. Retention time refers to the duration it takes for a particular analyte to elute from the system. Common solvents used in HPLC include any miscible combinations of water and organic liquids. Gradient elution techniques are often applied to adjust the composition of the mobile phase during analysis, facilitating the separation of analyte mixtures based on their affinity for the current mobile phase. The choice of solvents, additives, and gradients is determined by both the characteristics of the stationary phase and the nature of the analytes involved.(3)

METHOD DEVELOPMENT(4)

Method development by HPLC method involves following steps;

1. Understand the physicochemical properties of the drug molecule
2. Selection of chromatographic conditions
3. Developing the approach of analysis
4. Sample preparations
5. Method optimization

Understand the physicochemical properties of drug molecule

The physicochemical properties of drug molecule are essential for method development. Initially, it is important to assess the physical properties of the drug including polarity, solubility, pH and pKa. The polarity of a substance aids analysts in determining the appropriate composition of solvent and mobile phase. This relationship between polarity and solubility explains that compounds with similar polarities tend to dissolve in one another. Therefore, the solubility of the analyte is crucial for selecting suitable diluents. The pH value is a key factor in defining an acidity or basicity of substance. Selecting the correct pH for ionizable analytes often leads to symmetrical and sharp peaks in High-Performance Liquid Chromatography (HPLC). The pH is mathematically defined as the negative logarithm(base10) of the hydrogen ion concentration. $pH = -\log_{10}[H_3O^+]$ Choosing the right pH for ionizable analytes in HPLC often leads to sharp and symmetrical peaks. In quantitative analysis, these well-defined peaks are essential for achieving low detection limits, minimizing relative standard deviations between injections, and ensuring consistent retention times.(5)



**Selection of chromatographic conditions**

In the initial phases of method development, a preliminary set of conditions comprising the detector, column, and mobile phase is selected to produce the first "scouting" chromatograms for the sample. These conditions are usually centered around reversed-phase separations utilizing a C18 column with UV detection. At this stage, a decision must be made regarding whether to implement an isocratic or gradient elution method.(6)

Selection of column

The first and critical step in developing a method for High-Performance Liquid Chromatography (HPLC) is choosing the right stationary phase or column. A stable, high-performance column is vital for establishing a reliable and reproducible analytical procedure. Without an appropriate column, problems may occur due to inconsistent sample retention during the method development process. Generally, a C8 or C18 column constructed from highly purified, less acidic silica is recommended for separating basic chemicals and is versatile enough for a variety of sample types.

Column Diameter: The internal diameter can affect resolution and sensitivity.

Silica Substrate Quality: The purity and treatment of the silica influence performance.

Bonded Stationary Phase Characteristics: Different phases (e.g., C8, C18) provide varying selectivity and retention properties. Silica-based packing is favored in most contemporary HPLC columns due to its desirable physical properties. The primary components of HPLC column include the matrix, hardware and stationary phase. While silica is the most common matrix used, alternatives like polymers, alumina, and zirconium can also support the stationary phase. Silica matrices are particularly valued for their strength, ease of derivatization, consistent sphere sizes and resistance to compression under pressure. Additionally, they demonstrate chemical stability with most organic solvents and low pH solutions. However, limitation of silica as a solid support is its solubility at pH levels above 7, which can compromise its integrity in certain applications. Thus, careful consideration of pH stability alongside other factors is critical when selecting an HPLC column for specific analytical needs.(7)

Selection of chromatographic mode

The selection of chromatographic modes is affected by the molecular weight and polarity of the analyte. This discussion will concentrate on reversed-phase chromatography (RPC), which is the most commonly used technique for separating small organic compounds. RPC is especially effective for the separation of ionizable substances, such as acids and bases, by using buffered mobile phases to keep the analytes in their non-ionized state or by employing ion-pairing reagents.

Buffer selection

Various buffers, including potassium phosphate, sodium phosphate, and acetate, were evaluated for their compatibility factors and overall chromatographic performance.

General consideration for buffer selection;

Phosphate exhibits greater solubility in methanol/water mixtures than in acetonitrile/water or THF/water combinations. This property can significantly affect the selection of mobile phases in chromatography, particularly since some salt buffers are hygroscopic, which can lead to chromatographic challenges such as increased tailing of basic compounds and potential selectivity issues. Generally, ammonium salts are more soluble in organic/water mobile phases, making them advantageous for specific applications. Trifluoroacetic acid (TFA) is recognized for its volatility and low UV absorbance at certain wavelengths; however, it is prone to degradation over time, which requires careful handling. Additionally, microbial growth poses a risk in buffered mobile phases with minimal organic modifiers, as it can rapidly develop and accumulate on column inlets, negatively impacting chromatographic performance.(8) At pH levels above 7, phosphate buffers can significantly increase the dissolution of silica, which may lead to a reduced lifespan for silica-based HPLC columns. Consequently, it is recommended to use organic buffers when operating at elevated pH values. Ammonium bicarbonate buffers are particularly vulnerable to



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fluctuations in pH and generally remain stable for only 24 to 48 hours. The release of carbon dioxide from these buffers tends to raise their basicity over time. To maintain optimal performance and prevent contamination or degradation of mobile phases, it is crucial to filter buffers through a 0.2 μm filter and degas them prior to use.(9)

Buffer concentration

A buffer concentration ranging from 10 to 50 mM is typically adequate for small molecules. Generally, a buffer should not exceed 50% organic content, which is influenced by the specific buffer type and its concentration. The most frequently employed buffer systems in reversed-phase HPLC are phosphoric acid and its sodium or potassium salts. For the analysis of organophosphate compounds, sulfonate buffers can serve as an alternative to phosphonate buffers.(10)

Selection of mobile phase

The mobile phase is essential in reverse-phase high-performance liquid chromatography (RP-HPLC) as it significantly influences resolution, selectivity, and efficiency. The solvent composition, particularly its strength, is critical for effective separation. Common solvents used in RP-HPLC include acetonitrile (ACN), methanol (MeOH), and tetrahydrofuran (THF), which have UV cut-off wavelengths of 190 nm, 205 nm, and 212 nm, respectively. These solvents are completely miscible with water. When developing RP-HPLC methods, starting with a mixture of acetonitrile and water is often the most effective approach for the mobile phase.(11)

Selection of detectors

The detector is crucial in High-Performance Liquid Chromatography (HPLC). Several factors influence the choice of detector, such as the chemical composition of the samples, possible interferences, required detection limits, availability, and costs. Commonly used commercial detectors in liquid chromatography include UV detectors, fluorescence detectors, electrochemical detectors, refractive index (RI) detectors, and mass spectrometry (MS) detectors. Ultimately, the selection of a detector is determined by the specific properties of the sample and the goals of the analysis.(12)

Developing the approach of analysis

The development of an analytical method for Reversed Phase High-Performance Liquid Chromatography begins with the careful selection of various chromatographic parameters. These include the column, flow rate, mobile phase and pH, all of which are determined through a series of trials. Once these parameters are established, they are assessed against system suitability criteria.

System suitability parameters;

- Retention time: Should exceed 5 minutes
- Theoretical Plate Count: Must be greater than 2000
- Tailing factor: Should be less than 2
- Resolution: Needs to be over 5

Percent Relative standard Deviation (R.S.D.)

The area of analyte peaks in standard chromatogram should not exceed 2%. In methods that involve the simultaneous estimation of two components, the detection wavelength is usually set at an isosbestic point, where the absorbance of both species is equal. After optimizing these parameters, the laboratory combination is tested to assess the feasibility of the proposed method for simultaneous estimation. Following this, the marketed formulation is analyzed by diluting it to ensure it falls within the established concentration range for linearity. This systematic approach guarantees that the developed RP-HPLC method is both reliable and efficient for quantitative analysis in pharmaceutical applications.(13)



**Ashwini Waghchaure and Sharmila Naykar****Sample preparation**

Preparation of sample is a crucial phase in method development that analysts must thoroughly investigate. When dealing with samples containing insoluble components, it is essential to determine whether techniques such as centrifugation (including optimal rpm and duration), shaking or filtration are necessary. The primary objective is to ensuring that the filtering process does not compromise the analytical results by causing adsorption or extracting leachable substances.⁽¹⁴⁾ The effectiveness of syringe filters in removing contaminants and insoluble particles without introducing any unwanted impurities to a filtrate is a key factor in their selection. The analytical method should include a clearly defined sample preparation protocol which is used for actual in-process samples or dosage forms intended for subsequent HPLC analysis. This involves detailing the manufacturer, type, and pore size of the filter media. The primary goal of sample preparation is to produce a processed sample that yields more accurate analytical results than the raw sample. The prepared sample should be an aliquot that is largely free from interferences, compatible with the HPLC procedure, and safe for the column. This entails using a solvent that dissolves well in the mobile phase without negatively impacting sample retention or resolution. The process of sample preparation begins with sample collection and continues until the sample is injected into the HPLC column.⁽¹⁵⁾

The process involves several critical steps:

- **Sample Collection:** Utilize appropriate techniques to ensure representativeness and prevent contamination.
- **Sample Homogenization:** If necessary, achieve uniformity through methods like stirring or sonication.
- **Filtration:** Employ syringe filters to eliminate particulates that could hinder analysis, ensuring that selected filters do not leach contaminants into the sample.
- **Solvent Compatibility:** Ensure that the prepared sample dissolves effectively in the mobile phase used for HPLC, maintaining chromatographic integrity.

By adhering to these guidelines, analysts can prepare samples that are conducive to accurate and reliable HPLC analysis, ultimately leading to improved analytical performance.⁽⁸⁾

METHOD OPTIMIZATION

The traditional optimization of HPLC methods has often prioritized mobile phase conditions over stationary phase parameters, leading to an imbalance in method development. This approach can overlook essential interactions between the mobile and stationary phases that affect selectivity and resolution. Reliance on trial-and-error techniques, such as the one-factor-at-a-time approach, can result in inefficient testing processes and missed optimizations. Additionally, focusing narrowly on mobile phase optimization may not adequately address the variability introduced by different instrument setups or sample matrices, significantly impacting method performance and reproducibility. To enhance HPLC method optimization, several experimental design strategies can be employed. Chemometric approaches, including Full Factorial Designs (FFD) and Fractional Factorial Designs (FrFD), allow for the simultaneous evaluation of multiple variables, identifying significant factors and their interactions. Response Surface Methodology (RSM) can further explore relationships between experimental factors and responses, guiding the selection of optimal conditions. By utilizing screening designs and statistical analyses such as ANOVA, researchers can efficiently refine methods, addressing issues stemming from the traditional focus on mobile phase parameters. Assessing method performance in HPLC also involves investigating how various instrument setups and sample matrices influence results. Factors such as the type of detector used, column characteristics, and flow rates can vary significantly between different HPLC systems. Sample matrices play a crucial role as well; they can introduce matrix effects that alter retention times and peak shapes. Therefore, it is essential to evaluate method performance under various conditions to ensure robust method development. This comprehensive approach provides a clearer understanding of method robustness and reproducibility, leading to optimized conditions that effectively handle variability in real-world applications.⁽¹⁶⁾ The different components of the mobile phase—such as acidity, solvent type, gradient, flow rate, temperature, sample quantities, injection volume, and diluent solvent type—are crucial control variables for optimizing liquid chromatography (LC) methods. Once sufficient selectivity is attained, these factors play a key role in finding the optimal balance between resolution and



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analysis time. Furthermore, adjustments to parameters like column dimensions, particle size of the column packing, and flow rate can be made without impacting the capacity factor or selectivity.(10)

Key Factors Affecting HPLC Method Development(17)(15)

There are several key factors that can affect the development of a successful RPHPLC method. These factors can influence the separation and quantification of analytes in a complex mixture and can include the following:

- **Stationary phase:** The selection of the stationary phase is vital in the development of RP-HPLC methods. The surface chemistry of the stationary phase plays a key role in influencing its selectivity, capacity, and retention characteristics for different analytes. The most frequently utilized stationary phases in RP-HPLC include C18, C8, and phenyl-based phases. Choosing the right stationary phase is contingent upon the properties of the analytes and the desired separation mechanism.
- **Mobile phase:** The mobile phase plays a crucial role in the development of RP-HPLC methods. It must be optimized to achieve the desired selectivity, resolution, and sensitivity for the effective separation of analytes. Factors such as the ratio of water to organic solvent and the pH of the mobile phase can significantly influence the retention characteristics of the analytes.
- **Column dimensions:** The dimensions of a column, including its length and diameter, significantly influence the separation and quantification of analytes. Longer columns tend to enhance resolution, although they require more time for analysis. Conversely, wider columns can increase sample throughput, but this may lead to a decrease in resolution.
- **Flow rate:** The flow rate of the mobile phase in column significantly affects the separation and resolution of analytes. A flow rate that is too high may cause band broadening and reduced resolution, whereas a flow rate that is too low can lead to extended analysis times.
- **Gradient elution:** Utilizing a gradient elution profile can enhance the separation and resolution during the development of RP-HPLC methods. By adjusting the gradient, it is possible to optimize the separation of analytes according to their hydrophobic characteristics.
- **Detection method:** The selection of a detection method can significantly influence both the sensitivity and selectivity of the analysis. Common techniques include UV-Vis spectroscopy, mass spectrometry, and fluorescence spectroscopy. The appropriate detection method is determined by the characteristics of the analytes and the required sensitivity for the analysis.
- **Sample preparation:** Effective sample preparation is essential for successful development. This process may involve various steps, including extraction, purification, and derivatization, all aimed at enhancing the separation and quantification of analytes. The key factors that can affect RP-HPLC method development include the mobile phase, stationary phase, column dimensions, flow rate, gradient elution, detection method and sample preparation. Proper optimization of these factors can lead to the successful separation and quantification of analytes in complex mixtures.

Novel Technologies for RP-HPLC Method Development(18)

In recent years, new technologies have emerged to improve the efficiency and effectiveness of RP-HPLC method development. Here are some examples:

- **Advanced stationary phases:** The development of new stationary phases with improved selectivity and efficiency has been a major focus of research in RP HPLC method development. For example, core-shell particles have been developed with higher surface area and better packing efficiency than traditional fully porous particles.
- **Monolithic columns:** They are a single piece of stationary phase with a continuous network of pores. They offer faster separation times and lower backpressure than traditional particle-packed columns.
- **Ultra-High-Pressure Chromatography:** It uses columns packed with sub-2 μ m particles and operates at higher pressures than traditional HPLC, resulting in faster separations and improved resolution.
- **Two-dimensional liquid chromatography (2D-LC):** 2D-LC involves the separation of a sample using two different modes of chromatography. This technique can improve the separation of complex mixtures and has applications in proteomics and metabolomics research.



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- **Intelligent software for method development:** Intelligent software can aid in method development by automatically selecting optimal parameters based on experimental data, reducing the time and effort required for optimization. Collectively, these novel technologies have the potential to significantly improve the efficiency, sensitivity and selectivity of RP-HPLC method development. Researchers and practitioners should keep abreast of these developments and consider their potential applications in their own work.

VALIDATION

Validation studies in the pharmaceutical industry have been a focus for many years, but recent trends indicate a growing interest in quality assurance programs, which are crucial for efficient manufacturing processes. The concept of validation originated in the United States in 1987 and has since evolved to encompass a broader range of activities. These activities now encompass not only analytical techniques for quality control of drug ingredients and products but also computerized systems utilized in clinical trials, process management, and labeling.⁽¹⁹⁾ Validation plays a crucial role in current Good Manufacturing Practices (cGMP). In simple terms, validation refers to the assessment of validity or the process of ensuring effectiveness. It is a collaborative effort that involves team members from various departments within the industry.⁽²⁰⁾

Importance of Validation⁽¹¹⁾

- Assurance of quality
- Time-bound
- Process optimization
- Reduction of cost
- Nominal mix-ups and bottlenecks
- Minimal batch failure improved efficiency and productivity
- Reduction in rejections
- Increased output
- Avoidance of capital expenditures
- Fewer complaints about the process related failures
- Reduced testing in process and in finished products
- More rapid and reliable start-up of new equipment
- Easier scale-up from development work
- Easier maintenance of equipment's
- Improved employee awareness
- More rapid automation

COMPONENTS OF METHOD VALIDATION⁽²¹⁾

- Accuracy
- Precision
- Linearity
- Limit of detection and quantitation
- Specificity
- Robustness
- Range

Accuracy

The accuracy of an analytical method indicates how closely the measured value corresponds to a recognized true value or accepted reference value. This concept, often referred to as "trueness," reflects the level of agreement between these values. To evaluate accuracy in practical terms, one calculates the difference between the mean value obtained from several measurements and the actual true value. This assessment involves applying the analytical procedure to samples with known concentrations of the analyte, ensuring that any potential interference is



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considered by comparing the results with those from standard and blank solutions.(22)The accuracy is typically expressed as a percentage, reflecting the recovery rate of the analyte based on test results. Specifically, it is calculated as the percentage of the analyte recovered from the assay compared to the amount that was added. This metric serves as a crucial indicator of how well an analytical method performs in terms of measuring known quantities accurately.(23)

Precision

Precision denotes the degree of consistency among a series of measurements taken from multiple samples of a uniform material under controlled conditions. In analytical contexts, it reflects how closely related measurements are when derived from repeated analyses of the same sample. Precision is typically classified into three categories: repeatability, intermediate precision, and reproducibility. To quantify the precision of an analytical method, standard deviation or relative standard deviation of the dataset is commonly employed.(24) Precision denotes the consistency or repeatability of an analytical method under controlled conditions. Intermediate precision, commonly referred to as ruggedness, indicates the variability encountered within a laboratory environment, including variations that may occur on different days or with different analysts or equipment used in the same lab. To evaluate the precision of an analytical procedure, it is crucial to analyze a sufficient number of aliquots from a homogeneous sample to derive statistically reliable estimates of standard deviation or relative standard deviation.(15)

Linearity

Linearity refers to the capability of an analytical method to produce test results that are directly proportional to the concentration of the analyte within a specified range. When a method exhibits linearity, the test results correspond with the analyte concentration in samples, either directly or through a clearly defined mathematical transformation. This linearity is typically expressed in terms of the confidence interval surrounding the slope of the regression line. It is crucial to assess this linear relationship across the entire range of the analytical procedure. The proposed method involves demonstrating linearity directly with the drug substance by diluting a standard stock solution of the drug product components. According to ICH guidelines, at least five different concentrations should be utilized to establish linearity.(14)

Limit of Detection and Quantitation(25)

The limit of detection (LOD) refers to the minimum concentration of an analyte in a sample that can be identified, though not necessarily quantified accurately. In analytical methods characterized by baseline noise, LOD is often determined using a signal-to-noise (S/N) ratio of 3:1, which is typically expressed as the concentration of the analyte in the sample. Conversely, the **limit of quantitation (LOQ) is defined as the lowest concentration of an analyte that can be measured with acceptable precision and accuracy under specified operational conditions. The International Council for Harmonization (ICH) recommends a signal-to-noise ratio of 10:1 for LOQ. Both LOD and LOQ can be calculated using the standard deviation of the response (SD) and the slope of the calibration curve at concentrations near the LOD, employing the following formulas:

$$\text{LOD} = 3.3 \times \text{S/SD}$$

$$\text{LOQ} = 10 \times \text{S/SD}$$

Specificity

Specificity refers to the capability of an analytical method to accurately identify an analyte amidst other expected components, such as impurities, degradation products and matrix effects. When a method lack specificity, it may be complemented by additional analytical techniques to ensure accurate results. This definition encompasses several important aspects:

Implications of Specificity

- **Identification:** This involves confirming the identity of the analyte within a sample.



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- **Purity Testing:** Various analytical processes must be conducted to ensure precise characterization of impurity concentrations in the analyte. This includes tests for related substances, heavy metals, and residual solvents.

In essence, specificity is crucial for ensuring that analytical results reflect the true concentration and identity of the analyte without interference from other substances present in the sample.(26)

Robustness

The robustness of an analytical method refers to its ability to maintain stability despite minor, intentional variations in parameters such as pH, mobile phase composition, temperature, and instrument settings. This characteristic indicates the method's reliability under standard operating conditions.(22)

Range

The method's range refers to the interval between the upper and lower levels of an analyte that can be measured with suitable precision, accuracy, and linearity.(22)

CONCLUSION

This review offers an extensive examination of the development and validation processes for HPLC methods. Key findings emphasize the necessity of optimizing critical parameters such as the mobile phase composition, stationary phase and column temperature. These optimizations are crucial for enhancing the accuracy, sensitivity, and selectivity of analyses, which can lead to improved product quality and safety, as well as better environmental protection. Future research directions in Reverse Phase (RP) HPLC method development should focus on investigating new stationary phases and column technologies. Additionally, there is a need for advancements in sample preparation techniques and optimization strategies. The integration of **artificial intelligence** and **machine learning** into RP HPLC method development could significantly accelerate and improve the efficiency of these processes. Overall, this review underscores the importance of ongoing innovation in HPLC method development and highlights the necessity for collaboration between academic researchers and industry practitioners to further advance this field.

CONFLICT OF INTEREST

There is no conflict of interest.

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Exploring Sustainability and Profitability: A Systematic Review of Environmental, Social and Governance Factors

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ABSTRACT

As ESG factors increasingly impact corporate performance and investment strategies investors, understanding their relationship with financial outcomes for business organisations and investors are crucial. This literature review synthesizes findings from 71 studies on ESG's effects on performance, strategies, and investor behavior. The review encompasses diverse methodologies, regions, and time periods, utilizing academic journals articles and book chapters from the most recent database i.e, 2020 to 2025 time period. The main aim is to investigate the link between ESG and its relationship with investors' behaviour, investment strategy and company's profitability. The paper identifies research trends, and pinpoint research gaps. Using the PRISMA framework, this study provides a thorough analysis of ESG factors influencing investment decisions and corporate success. By integrating existing literature, this research enhances the discourse on ESG integration and its financial market implications, suggesting future research pathways in these vital domains.

Keywords: ESG factors, company performance, investment strategies, investor behaviour, systematic review, PRISMA framework





INTRODUCTION

E, S and G refers to Environmental, Social, and Governance (ESG) factors. The term **Environmental, Social, and Governance (ESG)** was coined in a 2004 report titled *Who Cares Wins*, initiated by the United Nations Global Compact in collaboration with financial institutions. The report emphasized integrating ESG factors into financial markets to create sustainable and responsible investment practices. Since its inception, ESG has experienced exponential growth, driven by increasing awareness of climate change, social inequality, and corporate accountability. Regulatory developments, such as the European Union's Sustainable Finance Disclosure Regulation (SFDR), and global frameworks like the UN Principles for Responsible Investment (PRI), have further propelled ESG adoption. Today, ESG assets are projected to surpass \$50 trillion by 2025, reflecting its pivotal role in influencing corporate strategy, investor behaviour, and global sustainability goals. The Environmental (E) component concerns a firm's ecological impact, including its climate policies, pollution control, waste management, and resource conservation strategies. Firms with robust environmental practices are generally perceived as more sustainable, attracting environmentally-conscious investors (Kulal et al., 2023) (Ahmad et al., 2023). The Social (S) dimension examines a firm's relations with its employees, patrons, and the neighbourhood, addressing topics like human rights, labour conditions, community contributions, and diverse representation. Social considerations are vital for fostering a favorable corporate reputation and ensuring long-term viability (Bhattacharya, 2022) (Gaurav & Aman, 2022). The governance aspect (G) involves the internal structures within a company, the processes for making decisions, adhering to legal standards, and being attentive to what stakeholders require. Effective governance includes transparency, accountability, and ethical conduct, which are crucial for building investor confidence and maintaining corporate integrity (Lee & Suh, 2022) (Turek, 2022). Collectively, these ESG factors offer a holistic framework for evaluating a firm's non-financial performance and sustainability potential, thus gaining prominence in investment evaluations (Nazarova & Лаврова, 2022) (Panagopoulos & Tzionas, 2023). Corporations are increasingly implementing ESG frameworks to boost transparency, mitigate risk, and drive long-term value. Concurrently, investors regard ESG compliance as indicative of resilience and competitive strength in uncertain economic conditions. This study investigates the progression of ESG investing, the ways it shapes corporate financial outcomes, investment strategy, and the behaviour of investors as a result of ESG practices adopted by Business organisations. By examining current patterns and practical studies, this document aims to clarify the essential function of ESG in promoting sustainable corporate behaviours and investment strategies.

RESEARCH QUESTIONS

1. What does the existing literature reveal about the integration of ESG practices or factors in companies and investors' decision-making process?
2. What are the unexplored research gaps for future research opportunities?

RESEARCH METHODOLOGY

To gather articles for this review, a comprehensive keyword search was conducted across various open-access databases and search engines, including SSRN, Google Scholar, Research Gate, Shodhganga, and DELNET, alongside selective use of subscription-based databases such as Scopus and the Web of Science. While numerous studies have been conducted on this topic since 2004, the focus was narrowed to literature published from 2020 onward to incorporate the most recent advancements in the field. Only peer-reviewed journal articles and book chapters were included in the review. To ensure a systematic and rigorous approach, the PRISMA framework was employed, facilitating a structured and transparent methodology for identifying, screening, and selecting relevant literature. This approach encompassed a thorough examination of both academic and grey literature sources, emphasizing a global perspective rather than focusing on specific demographics, to provide a holistic understanding of the research





domain. A total of 117 records were identified through database searches in Scopus, Web of Science, and open-access sources using keywords related to ESG, sustainability, investment, financial performance, and corporate strategies. After removing 22 duplicate records, 95 articles were screened for relevance. A further 24 articles were excluded based on language, publication period (2020-2025), study design, target topic relevance, and full-text availability, resulting in 71 full-text articles assessed for eligibility. Among these, 42 studies were included in qualitative synthesis, while 29 were selected for quantitative synthesis (meta-analysis). Ultimately, 71 articles formed the basis of the final synthesis, ensuring a comprehensive evaluation of ESG-related financial literature. The categories were created through an inductive process, starting with a careful review of the article abstracts (and sometimes the full text when the abstract was unclear or insufficient). This allowed us to identify the central focus of each study and spot common themes and distinctions across the articles. The criteria for categorizing the articles were based on their primary objectives, as well as a deeper understanding of their key findings. This process helped us identify areas that require further research and shed light on potential gaps in the field.

REVIEW OF LITERATURE DISCUSSION

The current body of knowledge reveals the vital importance of Environmental, Social, and Governance (ESG) components in directing investors' behavioural patterns, corporate financial results, and strategic investment frameworks. Governance and environmental criteria consistently emerge as pivotal determinants of investor choices, with younger investors demonstrating a pronounced propensity for sustainability, albeit characterized by a relatively low level of practical implementation. The effectiveness of ESG metrics shows a favourable connection with financial measures like Return on Assets (ROA) and Return on Equity (ROE), aiding in reducing risks during market declines; nevertheless, its effect on stock performance and shareholder returns seems to vary across different regions and sectors. In terms of investment strategies, the integration of ESG considerations enhances the quality of investment portfolios, diminishes volatility, and bolsters long-term sustainability objectives, particularly within institutional investment frameworks. Nonetheless, obstacles such as disparate disclosure standards and a lack of awareness in certain geographic areas persistently impede the effectiveness of ESG integration. These findings reinforce the critical role of ESG in promoting sustainable investment practices while simultaneously identifying avenues for further scholarly inquiry.

RESEARCH GAP

Despite extensive research on ESG factors and their impact on financial performance and institutional investment strategies, limited studies explore the nuanced relationship between ESG factors and individual investors. The existing literature predominantly focuses on institutional portfolios, leaving a gap in understanding how individual investors perceive and integrate ESG considerations into their decision-making processes. While governance and environmental criteria are consistently identified as critical drivers, the role of social factors remains underexplored, particularly in the context of personal investment preferences. Furthermore, variations in regional awareness, disclosure quality, and accessibility of ESG-related information hinder insights into the behaviour of individual investors across different demographics and markets. Despite significant studies conducted in other developing countries, research in the Indian context, especially in metropolitan cities where the majority of investors reside and ESG issues are more persistent, remains scarce.





CONCLUSION

This systematic literature review elucidates the dynamic interplay between investors' behaviour, company performance and ESG factors. It underscores the intricate nature of ESG adoption, particularly among individual investors in India's urban centres. Despite advancements in understanding institutional investment, a notable deficiency exists in grasping how individual investors assimilate ESG considerations. Additionally, the influence of social dynamics and regional disparities in investment practices, especially within developing contexts like India, necessitates further investigation. This study establishes a robust basis for subsequent research that could explore sector-specific details and demographic influences, thereby enhancing strategies for promoting ESG adoption among individual investors.

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Table 1: Keyword combination used to retrieve journal articles

ESG - related keyword	Investment - related keyword
ESG	invest*
	strateg*
	portfolio*
	practice*
	rating*
environment* social* govern*	invest*
	strateg*
	portfolio*
Sustain*	invest*
responsi*	invest*
ethic*	invest*





impact*	invest*
company	perform*
investor*	behavio*
retail	invest*

Table 2: Thematic categorisation of literature

Categories	Coding Criteria (Based on Objectives)	No of articles (71)
Investors response to ESG information and their behaviour	How do ESG factors impact investor decisions globally?	33
	What role does ESG data play in retail investment choices?	
	How do emotions affect ESG returns and volatility?	
	What drives Generation Z's interest in ESG investments?	
	How does corporate reputation influence ESG investment behaviour?	
ESG as an investing strategy	How do ESG factors influence investment strategy and decision-making?	15
	What is the role of ESG in optimizing portfolio performance?	
	How can investors integrate ESG principles into their investment strategies?	
	What impact do ESG disclosures have on investment strategy formulation?	
ESG practices and company's performance	What is the impact of ESG scores on the financial performance of companies?	23
	How do ESG ratings influence key financial metrics like ROA, ROE, and net profit margin?	
	How do ESG factors affect corporate profitability and stock prices or investment outcomes?	

Table:3 ESG factors and Investment Behaviour

S No	Authors	year	Purpose of the study	Findings
1	Ahmed El Oubani	2024	This research explores how investor emotions correlate with the returns and volatility of ESG indices in Morocco and Egypt, especially during key occurrences like COVID-19 and geopolitical conflicts	Investor sentiment notably affects ESG index returns and volatility, particularly in times of distress. When things are running smoothly, short-term spillovers are usual, yet during crises, long-term spillovers become increasingly noticeable.




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2	Kirti Sood, Prachi Pathak, Sanjay Gupta	2024	The research seeks to ascertain the prioritization of investment decision determinants by individual equity investors in the Indian stock market.	The foremost criteria included information accessibility, psychological heuristics, and economic indicators. The lesser criteria encompassed environmental concerns, broker advisements, and social matters.
3	Qianqian Lia , Edward M. Wattsb , and Christina Zhu	2024	To examine if retail investors integrate ESG news in their investment decisions in the US.	The findings suggest that retail investors consider ESG news. They prioritize financial outcomes of ESG news over non-financial preferences.
4	SWIKRITI UPADHYAY	2024	The research scrutinizes the ramifications of Environmental, Social, and Governance (ESG) criteria on the performance results of individual investors. It aims to elucidate the effects of ESG considerations on portfolio performance, risk management, and investor contentment.	Empirical evidence indicates a positive relationship between robust ESG performance and individual investor results. Businesses that achieve elevated ESG ratings generally reflect improved financial success, decreased capital expenditures, and optimal risk-adjusted earnings.
5	Wenzhou Qu and Zekai Su	2024	The study investigates the influence of fund signals, especially ESG ratings, on the investment behavior of Chinese investors and the resultant economic effects	Chinese investors frequently prioritize high-yield and well-rated funds, often overlooking ESG ratings. While traditional indicators like past performance do not reliably forecast favorable returns, ESG ratings demonstrate significant positive predictive capability.
6	XiaojiaZhang , Li Ma and Miao Zhang	2024	The analysis focuses on the link between retail investors' opinions about corporate ESG outcomes and their investment choices in China, with social self-efficacy acting as a moderating element.	The results reveal a favorable link between how Chinese investors view corporate ESG practices and their investment behaviors and goals. Understanding how ESG performance correlates with investment intentions hinges on the role of social self-efficacy.




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7	Yingxue Gao and Yan Chen	2024	This research explores how sustainable factors influence the choices of non-professional investors in China.	Non-professional investors exhibited a heightened tendency to invest in firms with ESG assurance. This tendency was further amplified when ESG assurance reports were presented independently and when the assured ESG indicators were more extensive.
8	Hannah Lea Weinbrenner	2023	To investigate the elements that impact Generation Z's tendency to put money into Environmental, Social, and Governance (ESG) funds with the aid of a broadened version of the Theory of Planned Behaviour (TPB)	The findings indicate that perceived investment ease, social norms, attitudes, perceived financial outcomes, risk assessment, and consumer efficacy significantly influence Gen Z's investment intentions toward ESG funds.
9	Bibek Karmacharya	2023	This study investigates the correlation between ESG factors and investment choices.	The findings revealed a notable positive effect of social and governance elements on investment decisions, while environmental factors exhibited no significant effect. The study
10	Eunyoung Cho	2023	To investigate the fluctuations in preferences for ESG investments within the Korean stock market.	The disparity in alpha between high-ESG and low-ESG stocks is more pronounced during prosperous periods. Individual investors exhibit a preference for high-ESG stocks during favorable economic climates.
11	Florian Heeb, Julian F. Kölbel, Falko Paetzold and Stefan Zeisberger	2023	The analysis delves into what drives investors' readiness to invest in sustainable options, especially highlighting the importance of social outcomes.	Investors exhibit considerable WTP for sustainable investments. This indicates that the WTP for sustainable investments is primarily influenced by the positive emotions tied to sustainability rather than by a rational evaluation of impact.




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12	Husnah Husnaha*, DjayaniNurdina and Muhammad Yunus Kasim	2023	To study the relationship between Environmental, Social, and Governance (ESG) considerations and investment selections, with investment targets acting as an intermediary.	Environmental considerations significantly affect investment goals but not the decisions themselves. Social elements positively affect investment decisions while leaving objectives unchanged. Corporate governance influences both investment goals and decisions. The relationship between ESG aspects and investment selections is guided by investment aims.
13	Inga Pašiušienė, AskoldasPodvievko, Daiva Malakaite, Laura Žarskienė, Aušra Liučvaitienė and Rita Martišienė	2023	The research seeks to analyze Generation Z students' investment behaviors, focusing on their propensity for green investments and enhancing financial literacy	The findings indicate that while Generation Z students exhibit rational investment tendencies, they are reluctant to actualize their theoretical endorsement of green investments. The predominant rational investor archetype identified is the pragmatist/framer/realist (PFR)
14	Nafisa Rounok ,Aimin Qian , Mohammad Ashraful Alam	2023	To ascertain the influence of ESG issues on investor decision-making with the mediating role of corporate reputation in the ESG-investment nexus.	ESG issues exert a substantial impact on investment choices along with Corporate reputation as a mediator in the ESG-investment decision relationship.
15	Nguyen Thi Phuong Dzung * , Phan Huy Toan , Le Trung Hieu , Nguyen Thi Linh , Hoang Thi Hang	2023	The research examines ESG report effects on Vietnamese investors' decisions	Governance information has the greatest influence, succeeded by Environmental and Social data.
16	Richa Bhatia, Narinder Kumar Bhasin, Sunil Kadyan and Preeti Singh	2023	This study explores how individual investors view ESG investing and how factors like asset familiarity, risk tolerance, and behavior influence their choices.	ESG elements notably affect investment choices. The research underscores the necessity of incorporating ESG factors into investment strategies for sustainable outcomes.




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17	Roman Kräussl, Tobi Oladiran, Denitsa Stefanova ²	2023	This study analyzes investor expectations and perceptions regarding ESG factors in investment choices to enhance performance or societal impact.	ESG funds exhibit inferior long-term performance, while demonstrating superior short-term results.
18	Samina Rooh ¹ , Hatem El-Gohary ^{2,*} , Imran Khan ³ , Sayyam Alam ⁴ and Syed Mohsin Ali Shah	2023	The research examines investor decision-making on the Pakistan Stock Exchange, with a focus on Environmental, Social, and Governance (ESG) factors.	The findings indicate that ESG considerations significantly influence investor choices. The emphasis on ESG issues has both theoretical and practical ramifications for firms, regulators, and investors in developing economies.
19	Abdelkbir ELOUIDANI, Ahmed OUTOUZZALT and Rania EL OUIDANI	2022	To delineate the environmental, social, and corporate governance determinants affecting the investment decisions of Moroccan individuals. To elucidate the interconnections among these determinants	Social and governance criteria are pivotal factors that directly impact investment intentions and indirectly affect stock market engagement.
20	Heena Thanki ¹ , Sweetie Shah ² , Harishchandra Singh Rathod ¹ , Ankit D. Oza ³ and Dumitru Doru Burduhos-Nergis	2022	To investigate the influence of collectivism, environmental concerns, financial performance, and awareness of SRI on investment propensity in socially responsible investments.	The study concludes that collectivism, environmental concerns, financial performance, and awareness of SRI positively shape attitudes toward SRI, thereby affecting investment intentions.
21	Kirti Sood and Prachi Pathak, Jinesh Jain and Sanjay Gupta	2022	The research seeks to discern key ESG factors that affect equity investor decisions.	Governance emerged as the predominant factor, succeeded by environmental criteria, with social criteria being the least impactful.
22	Mehwish ¹ , Mustafa Afeef, Shahid Jan Kakakhel	2022	The research investigates the impact of ESG factors on individual investors in the PSX.	The findings indicate that governance factors predominantly affect investment choices, succeeded by social and environmental aspects. Investors exhibit sensitivity to ESG factors, which exert a favorable influence on their investment decisions.




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23	Mehwish ¹ , Mustafa Afeef ² , Shahid Jan Kakakhel ³	2022	To examine the influence of ESG factors on investment behavior.	Theoretically, Individual attitudes are influenced by beliefs that drive specific behaviors. The results advocate for investor preference towards companies that prioritize ESG factors to protect capital and enhance cash flow.
24	Ruiying Li	2022	To conduct a systematic review of the evolution of ESG investment across several dimensions. ESG has gained prominence amid escalating global challenges.	ESG investment emerges from stakeholder interests, advancing societal development via financial mechanisms.
25	So Ra Park and Kum-Sik Oh	2022	To investigate the incorporation of ESG data by individual investors. To enhance comprehension of the motivators for individual investors' adoption of ESG information	Discovers vital components like performance expectancy, effort expectancy, social influence, and conditions that facilitate ESG data integration. Proposes that the standardization of ESG reporting may promote the assimilation of ESG information.
26	Surbhi Verma and Ashu Khanna	2022	The study aims at assessing the influence of Social Value Orientation and Emotional instability on the choice of socially responsible investment (SRI) funds in association with Financial Risk Tolerance	SVO, EI, age, marital status, and gender serve as significant determinants of FRT. Investors with pro-social orientations demonstrate a greater propensity for SRI fund investment. Emotional instability exerts a detrimental effect on risk tolerance.
27	Ran Chang, Xiaoyan Zhang, Xinran Zhang	2022	The research aims to investigate whether retail investors utilize ESG (Environmental, Social, and Governance) information in their trading decisions, specifically analyzing stock-level data from 2010 to 2019 in the US to understand the relationship between ESG information and retail trading behavior	Retail investors are more active in trading stocks with high ESG scores, and their net buying in these stocks shows a stronger positive predictive power for future stock returns compared to stocks with lower or no ESG information




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28	Dhaval Prajapati, Dipen Paul, Sushant Malik, Dharmesh K. Mishra	2021	The research investigates the determinants affecting retail investors' choices regarding green bonds in India.	The findings indicate that ESG ratings, credit ratings, tax incentives, and awareness significantly affect investment behavior. Financial advantages outweigh environmental considerations in influencing investment.
29	Ritika Seth, Shubham Gupta, Harshita Gupta	2021	The research endeavors to rigorously assess ESG Investing and Sustainable Finance in India, emphasizing its concept, significance, scope, elements, limitations, and future prospects	ESG investing is increasingly favored by younger investors and financial institutions. The study observes a positive correlation between ESG practices and financial outcomes, albeit with occasional inconclusiveness.
30	Rob Bauer, Tobias Ruof and Paul Smeets	2021	This study examines the motivations behind individuals' preferences for sustainable investments and their impact on pension fund policies	Most participants supported increasing fund engagement with firms aligned with specific Sustainable Development Goals (SDGs), despite potential adverse effects on financial returns. Social preferences significantly influenced this decision.
31	Satyabrata Aich, Ayusha Thakur, Deepanjan Nanda, Sushanta Tripathy, and Hee-Cheol Kim	2021	To analyze the correlations between ESG factors and their prioritization in terms of driving force in investment contexts	Ten significant factors influencing ESG's impact on investment were identified. A driver-dependence diagram was created to evaluate the driving and dependence relationships among these factors.
32	So Ra Park and Jae Young Jang	2021	To develop a tailored ESG model for South Korea. To ascertain the relative importance of factors reflecting investor perceptions.	Institutional investors prioritize environmental and governance aspects over social considerations. Key elements in investment choices include shareholder rights, pollution control, greenhouse gas emissions, and risk management





33	Muhammad Naveed1 , Muhammad Khalid Sohail2 , Syed Zain ul Abdin3 , Madiha Awais4 , Noshaba Batool5 Bahria University, Islamabad12 , Air University Islamabad35 , Lecturer, The Univeristy of Lahore4	2020	The research investigates the role of ESG (Environmental, Social, and Governance) data in the asset allocation choices of individual investors within the Pakistan Stock Exchange (PSX).	ESG information significantly influences individual investors' asset allocation decisions. Environmental and governance information have a greater impact than social information.
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Table:4 ESG as an investment strategy

S No	Authors	Year	Purpose of the study	Findings
1	Y.S. Yan	2024	This examination diligently evaluates ESG investment frameworks, revealing insights into the incorporation of ESG elements into investment strategies and their role in enhancing sustainable value and benefiting society.	The investigation reveals the significance of merging ESG (Environmental, Social, and Governance) principles within investment tactics for promoting sustainable value and societal progress, suggesting that responsible investing plays a pivotal role in the global financial landscape.
2	Pranav Saraswat, Gopika Juneja, Sandeep Kautish	2024	It investigates the shift from traditional profit-centric strategies to ethical and green investments, stressing the significance of societal awareness and corporate growth in contemporary investment strategies	The European Fund Management has recorded a 60% ESG integration adoption rate over recent decades, reflecting a substantial rise in ESG assets and a more comprehensive approach to corporate development.
3	Dmytro Zatonatskiy	2024	This article aims to systematically analyze various methodologies for integrating ESG principles within the strategic frameworks of investors and corporations	It assesses the implications of ESG regulations on businesses and investors, underscoring the importance of compliance to avoid reputational harm and financial penalties
4	Danyang Xu, Shaen Corbet, Chunlin Lang, Yang Hu	2024	This research investigates return interconnectedness and portfolio performance of six global ESG ETFs from 2020 to 2023 using a TVP-VAR methodology and varied portfolio strategies	Findings suggest that European ESG ETFs significantly influence the global ESG investment domain, attributed to their substantial market size and maturity that facilitate considerable portfolio volatility reduction




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5	Fisnik Morina, Saimir Dinaj	2024	It aims to elucidate the impact of ESG factors on investors and corporations, elucidating the link between financial performance and ethical business practices	The research underscores the role of institutional investors and regulatory changes regarding ESG disclosures, revealing the benefits of sustainable practices in attracting institutional investment and reducing risks.
6	Niamh O'Sullivan	2024	The research examines how institutional investors can utilize their influence to enhance the ESG practices of investee companies, thereby mitigating financial risks and maximizing long-term portfolio value.	Institutional investors are compelled to address ESG factors from a risk management standpoint due to the potential financial hazards linked to companies exhibiting inadequate environmental and social practices and deficient governance.
7	António Augusto Baptista Rodrigues	2024	To comprehend responsible investment strategies and their significance within the investment and asset management sectors	Responsible investment (IR) has gained significant traction in the investment and asset management industry, with assets utilizing IR strategies amounting to \$22.9 trillion globally, which constitutes 26% of all professionally managed assets. This indicates a growing recognition of the importance of integrating ESG (Environment, Social, and Governance) factors into investment decisions
8	Eigil Ingebreetsen	2023	The manuscript underscores the criticality of ESG factors as foundational in investment strategies, stressing the necessity for addressing essential elements for effective ESG integration.	It elucidates methods to integrate ESG factors throughout the investment process, encompassing strategic allocation, security selection, portfolio construction, risk assessment, stress testing, and compliance, with illustrative examples demonstrating portfolio alignment with ESG principles.




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9	Erick Meira, Felipe Arias Fogliano de Souza Cunha, Renato J. Orsato, María del Mar Miralles-Quirós, José Luis Miralles-Quirós	2022	The paper aims to assess a range of ESG investment strategies across the globe by analyzing daily closing prices of ESG best practices indices from 2011 to 2021, alongside market portfolio proxies and the risk-free rate	The research findings indicate a significant level of differentiation in the governance factor across all regions studied, while the environmental and social aspects showed a strong correlation with similar risk-return profiles
10	О. В. Ефимова, М. А. Волков, Д. А. Королёва	2021	The primary objective of the research is to assess the efficiency of investment decision-making by considering the requirements of sustainable development, specifically focusing on the relationship between environmental, social, and governance (ESG) performance and market returns for investors	The study concludes that portfolios of ESG-oriented companies demonstrate profitability. This indicates that ESG commitment can be a significant driver of market profitability for investors.
11	Pandu Adi Cakranegara, Filson MaraturSidjabat	2021	The research aims to examine how Environmental, Social, and Governance (ESG) factors affect firm value at the industry level, specifically focusing on the agricultural and mining sectors in Indonesia	The research findings of the paper indicate that Environmental, Social, and Governance (ESG) factors have a significant impact on the competitive advantage of companies and industries, with companies ignoring ESG values experiencing a decrease in competitiveness
12	Austin Moss, James P. Naughton, Clare Wang	2020	The research examines the impact of ESG disclosures on retail investors' portfolio decisions, particularly on platforms	The findings reveal that ESG disclosures do not affect retail investors' portfolio decisions, as their reactions to ESG press releases resemble regular adjustments on non-event days, suggesting a lack of prioritization of ESG information
13	Fabio Alessandrini, Eric Jondeau	2020	To propose an investment strategy that optimizes portfolio ESG quality while adhering to regional, sectoral, and risk factor constraints, thereby addressing limitations of conventional ESG screening	The research indicates that adherence to ESG criteria over the past decade has enabled investors to substantially improve portfolio ESG quality without sacrificing financial returns.




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14	Benjamin Hübel, Hendrik Scholz	2020	This paper seeks to employ return-based ESG exposures for assessing ESG risks, thereby facilitating a deeper comprehension of the influence of ESG factors on portfolio performance and risk within asset management	The research delineates three ESG risk factors (Environmental, Social, and Governance) that significantly augment the predictive capability of conventional asset pricing models, revealing that high ESG risk exposure portfolios exhibit increased risks; nonetheless, investors may construct portfolios with diminished ESG risks without adversely affecting risk-adjusted returns
15	Ying Chan, Ked Hogan, Katharina Schwaiger, Andrew Ang	2020	The study aims to illustrate the incorporation of Environmental, Social, and Governance (ESG) signals into factor-based investment strategies, indicating their economic alignment with general factor premiums	It seeks to demonstrate the enhancement of conventional financial value and quality factors through the integration of sustainable signals, exemplified by green intangible value and corporate culture quality, thus optimizing factor exposures with ESG and carbon metrics.

Table:5 ESG and Company Performance

S No	Author/s	year	Purpose	Findings
1	Kelvin Lee Yong Ming, YamunahVaicondam, Amira Mas Ayu Amir Mustafa, Siti Nurul Munawwarah Roslan, Yi Shen, Komal Chopra, Pooja Khanna	2024	The research investigates the influence of environmental, social, and governance (ESG) scores on the financial performance, particularly return on assets (ROA), of major publicly listed Malaysian firms from 2015 to 2022 through multiple regression analysis and generalized method of moments.	The research reveals a noteworthy positive correlation between the overall ESG metrics and ROA, implying that strong ESG initiatives can enhance financial performance for prominent publicly traded firms in Malaysia.
2	Eko Putri Setiani, Patriani Wahyu Dewanti, Estefanie Cortez	2024	This analysis examines the link between ESG evaluations and the economic performance of Southeast Asian businesses from 2019 to 2023.	The study indicates a positive correlation between ESG scores and financial performance in Southeast Asian firms, with stronger effects in low carbon emission companies.





3	Mishu Tripathi, Shuchi Gautam	2024	To analyze the effect of ESG Risk Rating on the financial metrics of NIFTY 50 companies, including return on assets, equity, investment, earnings per share, and net profit margin.	The study underscores the critical role of ESG factors in shaping corporate financial outcomes, advocating for improved ESG ratings to bolster financial performance
4	Rafał Buła, Monika Foltyn-Zarychta, Dominika Krawczyńska	2024	The study investigates how carbon emissions influence the relationship between ESG and financial performance in diverse companies	The results demonstrate a significant mutual effect of corporate governance on efficiency and a similar relationship between controversies score and efficiency.
5	Cosmin-Dănuț Vezeteu, Raluca-Ioana Stănculescu	2024	Evaluate the ESG risk scores of Romanian firms and their relationship with financial outcomes.	The research reveals no meaningful link between ESG factors and financial performance metrics like ROE, ROA, and Tobin's Q; nonetheless, a notable positive correlation is observed between Exposure and Management scores in relation to firm size, as evidenced by Market Capitalization.
6	Qingjing Wang	2024	This paper systematically reviews the relationship between ESG ratings and enterprise performance, emphasizing the importance of ESG evaluations for assessing sustainable development capabilities	The study asserts that ESG ratings propel enterprises towards sustainable practices and foster their long-term sustainable development




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7	Abhinandan Kula1*, Abhishek N2, Sahana Dinesh3, Divyashree M.S.4	2023	To examine the correlation between ESG factors and equity valuations as well as investment outcomes of companies	Firms exhibiting robust ESG performance generally achieve elevated stock valuations and superior investment outcomes. ESG factors hold significance irrespective of organizational scale, profitability, or sector.
8	Abhishek Parikh a, Divya Kumari a, Maria Johann Duřsan Mladenovic	2023	The research investigates the correlation between ESG scores and shareholder wealth within the Indian context	The governance aspect enhances equity returns, whereas the environmental aspect detrimentally affects them. The social factor's influence is determined to be negligible.
9	Sing On Lo	2023	This study focuses on the infringement of investment principles concerning ESG factors and shareholder wealth maximization.	Empirical findings indicate minimal influence of ESG ratings on stock returns in select markets, alongside a non-linear relationship between stock performance and high-ESG funds.
10	Anastasia Strekalina, Renata Zakirova, Alena Shinkarenko, Evgenii Vatsaniuk	2023	Investigate how ESG scores, their components, and additional financial metrics influence accounting (ROA), market (TSR), and economic (EVA spread) indicators in emerging BRIC countries' companies	Results indicate that the social and environmental aspects of ESG ratings positively influence Total Shareholder Return (TSR), enhancing market performance of the sampled firms.
11	Yi Fang	2023	It seeks to demonstrate the beneficial link between increased ESG scores and improved accounting and financial performance of A-Share companies of China	The findings indicate a significant relationship between high ESG scores and improved accounting performance in A-share companies in China




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12	Юлия Мартынова, Ирина Лукина	2023	To analyze the differential impacts of ESG ratings on financial performance in South-West and South-East Asia	ESG ratings positively influenced financial performance in South-West Asia, whereas no such effect was noted in South-East Asia. - In South-West Asia, specific ESG factors significantly enhanced financial ratios, unlike in South-East Asia, where ESG factors had no observable impact.
13	Satish Saini	2023	This study investigates the advantages of ESG ratings for corporate profitability.	The research indicates a correlation between heightened Sustainability awareness and increased corporate disclosure of ESG-related information, reflecting the importance of ESG factors in achieving business success and profitability
14	Emmerson Chininga, Abdul Latif Alhassan, Bomikazi Zeka	2023	- The research objective of this paper is to examine the effect of ESG ratings and its dimensions (environmental, social, and governance) on the financial performance of JSE-listed firms included in the FTSE/JSE Responsible Investment Index between 2015-2019	The study demonstrates that ESG investments enhance financial performance indicators for JSE-listed firms in the FTSE/JSE Responsible Investment Index. - The research highlights that environmental initiatives notably improve financial and market outcomes, whereas social and governance practices exhibit negligible effects on these performance metrics.
15	Biki Digar	2023	This paper explores the link between ESG scores and financial metrics in chosen Indian enterprises, particularly focusing on ROA, ROE, and ROCE	The study established a significant positive correlation between ESG performance and firm performance metrics like ROA, ROE, and ROCE.





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16	Jacob Azaare, Zhao Wu, Ping Li, Enock Mintah Ampaw	2023	Analyze the influence of ESG scores on the financial performance of German Stock Exchange companies from 2011 to 2021. - Assess the relationship between sustainable investments and financial performance in high ESG score firms.	Findings reveal that elevated ESG scores enhance financial performance through increased systematic risk, potentially elevating stock returns. - The study established a Granger causality indicating that ESG scores negatively Granger cause firms' market-based financial performance (Tobin's Q)
17	Seog-Soo Kim, Jae-Kyung Jung	2023	It aims to assess the effects of ESG integration, environmental, social, and governance ratings on accounting metrics such as ROA and market indicators like Tobin's Q	Findings indicate that ESG integration and its respective ratings positively impact Return on Assets (ROA) as an accounting metric.
18	Yu Wei He	2023	To assess the effect of ESG performance on corporate valuation utilizing data from Chinese public firms over five years.	The analysis shows a clear positive association between corporate valuation and ESG performance, relying on figures from Chinese listed companies from 2017 to 2021.
19	Ashutosh Yadav	2022	To investigate the link between ESG ratings and stock performance in Indian firms amid policy-induced economic instability.	Companies with superior ESG ratings exhibit enhanced stock performance relative to those with inferior ratings during such uncertainties. The social aspect of ESG emerges as the most critical determinant.
20	Helena Sandberg, Alhamzah Alnoor, Victor Tiberius	2022	To examine the influence of ESG ratings on financial outcomes in the European food sector.	The investigation suggests a modest effect of ESG ratings on financial performance, corroborating prior studies that indicate a positive association.



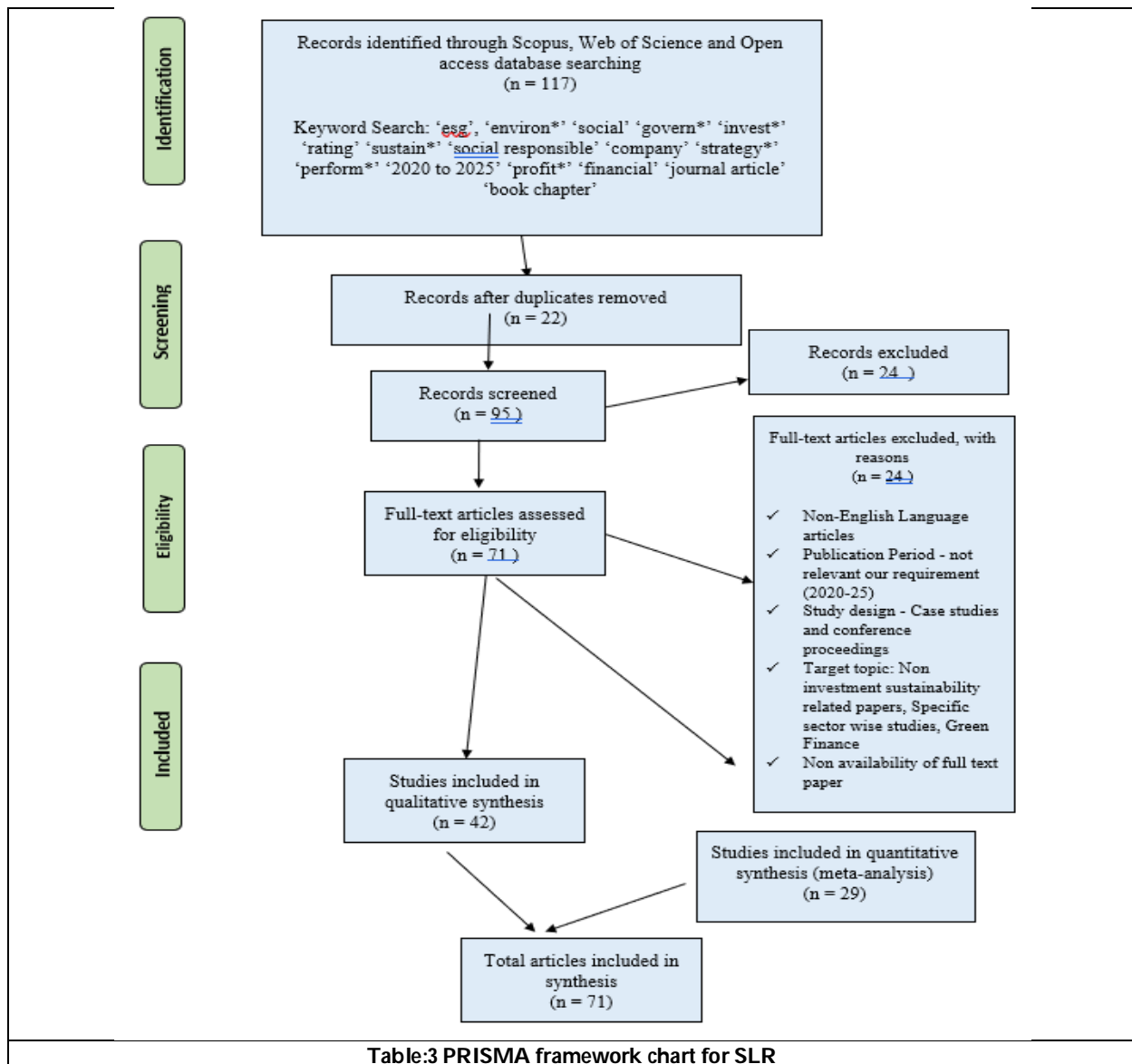

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21	Bharat Kumar Meher ¹ , Iqbal Thonse Hawaldar ² *, Latasha Mohapatra ³ , Cristi Spulbar ⁴ Ramona Birau	2020	This study evaluates the volatility and returns of Indian firms and examines the influence of ESG scores on these metrics.	The observed negative correlation between select ESG factors and returns suggests either the inadequacy of ESG disclosures in Indian sustainability reports or the possibility that investors overlook these scores during investment decisions.
22	Boffo, R., and R. Patalano	2020	To understand the impact of ESG ratings on long-term investment performance and the extent to which ESG approaches incorporate financially-material information.	The report highlights that while high ESG scores don't necessarily translate to better financial performance, portfolios with strong ESG ratings tend to experience lower risks during market downturns.
23	Mathias Dyrholm Paulsen	2020	The research investigates the impact of ESG and controversies on European company returns, emphasizing the connection between ESG performance and financial outcomes.	The findings suggest that ESG scores do not have a clear or consistent impact on returns. While low ESG scores show slightly negative returns, the effect is not strong enough to be conclusive, and higher ESG scores don't guarantee better returns either.





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Sustainable Production Inventory Model with Different Demand Patterns

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ABSTRACT

Sustainability is an essential component of every green production process. The production sectors embed various green costs parameters to assure and promote environmental sustainability. This research work extends a sustainable production-based inventory model with different demand patterns of linear, exponential and logarithmic. The objective of this research is to examine the changes of green cost parameters on optimal production quantity $q(t)$ under various demand conditions. A system of linear differential equation-based modelling approach is proposed and solved in Python environment. The sensitivity analyses are performed to determine the effects of parametric changes on $q(t)$. This research work provides various insights on green cost parameters and certainly makes significant contribution to the existing literature on green inventory models. The sustainable model considered in this work shall be further extended by discussing with other types of demand patterns. This deterministic model shall also be further explored by considering uncertainty, impreciseness and indeterminacy existing in the production scenario.

Keywords: Sustainability, Inventory Model, Production, Green costs, Demand Patterns.



**Theeba and Nivetha Martin**

INTRODUCTION

The promotion of environmental sustainability in a production sector leads to the ecological balance. In the industrial context, sustainability shall be discussed in the core dimensions of resource utilization, supply of resources, environmental impact, life cycle management and social responsibility. Sustainability is driven by environmental oriented activities paving to the mitigation of pollutant emission and waste discharge. Incorporation of green costs parameters into the manufacturing production system is essential in institutionalizing sustainable production sectors contributing to carbon neutrality. Hence, integrated sustainable inventory models encompassing green costs components and common inventory costs are required to set a balance between both the economic optimization and environmental conservation. The development of such integrated inventory models with different demand patterns is also crucial to characterize various manufacturing circumstances. The saturation of demand with respect to the changes in price and other decisive factors should be reflected in the inventory model for the decision makers to make decisions on optimal production quantity and time. Sustainable inventory models possess added value to both inventory management and environmental sustainability. Researchers have developed sustainable models considering various green costs pertinent to waste handling. Rework inventory models, reverse supply chain models also exist in literature addressing different facets of waste and pollution management especially carbon emissions and preservation technology. However, sustainable inventory model with different demand patterns and typical green costs do not exist in the recent literature. Hence, this research work contributes to the literature of sustainable inventory model by developing an inventory model with different demand patterns consisting green costs subjected to green energy, waste disposal methods, green packaging and green rework. The objective of this research is to develop a more comprehensive sustainable inventory model with different demand patterns encompassing possible sustainable costs. This work is an extension of the earlier model developed by the authors. The contents of the paper are organized into following sections. The literature review is outlined in section 2. The integrated sustainable inventory model is formulated in section 3. The model is analyzed and the inferences of the sensitivity analysis are presented in section 4. The last section concludes the work.

LITERATURE REVIEW

This section presents a brief presentation of the recent developments of sustainable inventory model with green cost components. The following table carries the nature of the demand and types of green cost incorporated in the recent literature. The research gaps and novel contributions in this research work are also presented. From the above Table, it is evident that the sustainable oriented inventory models comprise different green costs pertaining to preservation technology, carbon emission with different demand patterns. The sustainable costs are at times generic with not much specification. Also, the discussion on the effects of different demand patterns in a sustainable inventory model is not much explored to the best of our knowledge. This has motivated the authors to formulate an inventory model encompassing different green costs under various demand patterns.

Model Development

This section presents the notations, assumptions and formulation of an inventory model as follows. The model developed in this section is based on the proposed work of the authors on the sustainable inventory model and in this section, the model is discussed under different demand patterns.

Notations

P – Production

D – Demand

W – Number of defective items

T – Total Production time

C_1 – Constant carrying cost per unit time

C_2 – Fixed Ordering cost





TAC – Total average cost

$0 \leq t \leq t_1$

r – Rework rate of the defective items

G_T – Green Repairing technology initialization cost

g_t – Green Repairing cost per defective unit

$t_1 \leq t \leq T$

G_{di} – Incineration Disposal Initialization cost

g_{di} – Incineration kind of disposal cost on non-repairable items $j(1-r)$

G_{dL} – Landfilling Disposal Initialization cost

g_{dL} – Landfilling kind of disposal cost on non-repairable items $(1-j)(1-r)$

G_P – Green packaging cost

G_L – Green labelling cost

G_E – Green energy cost

Assumptions

1. The demand follows different patterns
2. Shortages are not allowed

This section consists of the formulation of a sustainable inventory model with different demand patterns and green cost parameters. Let us consider a production system, with production rate P and demand rate D where $P > D$. Let W be the number of defective items generated during the production run during the time interval $[0, t_1]$. Let r be the rework rate of defective items and a portion of rW is added to the demand during the time interval $[t_1, T]$. The portion of $(1-r)W$ is generated as waste and disposed using different waste disposal methods. The following production system is modelled as follows

$$\frac{dq(t)}{dt} = P - W - D \quad 0 \leq t \leq t_1$$

$$\frac{dq(t)}{dt} = -(D + rW) \quad t_1 \leq t \leq T$$

Case (i) Demand is Linear

In this case, the demand is assumed to be linear of the form $D = a_1 + b_1 q(t)$, which expresses the relationship between the quantity and the price. Here, a_1 is the constant term and b_1 is the slope of the demand function indicating the changes in the price with respect to the change in demand.

$$\frac{dq(t)}{dt} = P - W - (a_1 + b_1 q(t))$$

$0 \leq t \leq t_1$

$$\frac{dq(t)}{dt} + b_1 q(t) = P - W - a_1 \quad (1)$$

$$\frac{dq(t)}{dt} = -(a_1 + b_1 q(t) + rW) \quad t_1 \leq t \leq T$$

$$\frac{dq(t)}{dt} + b_1 q(t) = -(a_1 + rW) \quad (2)$$

Integrating Equation (1) and (2) we get

$$q(t)e^{b_1 t} = (P - W - a_1) \int_0^t e^{b_1 t} dt + c$$

$$q(t)e^{b_1 t} = \frac{(P - W - a_1)}{b_1} (e^{b_1 t} - 1) + c$$

$$q(t) = \frac{(P - W - a_1)}{b_1} (1 - e^{-b_1 t}) + c \quad (3)$$

$$q(t)e^{b_1 t} = - \int_{t_1}^t (a_1 + rW) e^{b_1 t} dt$$

$$q(t)e^{b_1 t} = - \left(\frac{a_1 + rW}{b_1} \right) (e^{b_1 T} - e^{b_1 t}) + c$$

$$q(t) = - \left(\frac{a_1 + rW}{b_1} \right) (e^{b_1 (T-t)} - 1) + c$$





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With initial condition $q(0) = 0$ (4)

And boundary condition $q(T) = 0$ (5)

We get $c = 0$

By (3) and (4) we get

$$q(t) = \frac{(P-W-a_1)}{b} (1 - e^{-b_1 t}) \quad (6)$$

$$q(t) = -\left(\frac{a_1 + rW}{b_1}\right) (e^{b_1(T-t)} - 1) \quad (7)$$

Let $q(t_1) = I_{max}$ (8)

$$I_{max} = \frac{(P - W - a_1)}{b} (1 - e^{-b_1 t})$$

$$I_{max} = -\left(\frac{a_1 + rW}{b_1}\right) (e^{b_1(T-t)} - 1)$$

$$\frac{(P - W - a_1)}{b} (1 - e^{-b_1 t}) = -\left(\frac{a_1 + rW}{b_1}\right) (e^{b_1(T-t)} - 1)$$

$$(P - W - a_1)(e^{b_1 t} - 1) = -(a_1 + rW)(e^{b_1 T} - e^{b_1 t})$$

$$e^{b_1 T} = e^{b_1 t} - \left(\frac{(P - W - a_1)(e^{b_1 t} - 1)}{a + rW}\right)$$

$$\log e^{b_1 T} = \log \left(e^{b_1 t} - \left(\frac{(P - W - a_1)(e^{b_1 t} - 1)}{a + rW}\right) \right)$$

$$T = \frac{1}{b} \log \left(e^{b_1 t} - \left(\frac{(P - W - a_1)(e^{b_1 t} - 1)}{a + rW}\right) \right) \quad (9)$$

$$\text{Holding Cost} = C_1 \left[\int_0^{t_1} q(t) dt + \int_{t_1}^T q(t) dt \right]$$

$$= C_1 \left(\int_0^{t_1} \frac{(P-W-a_1)}{b} (1 - e^{-b_1 t}) dt - \int_{t_1}^T \left(\frac{a_1 + rW}{b_1}\right) (e^{b_1(T-t)} - 1) dt \right)$$

$$\text{Holding Cost} = C_1 \left(\left(\frac{P-W-a_1}{b_1}\right) \left(t_1 + \frac{(e^{-b_1 t_1} - 1)}{b_1}\right) + \left(\frac{a_1 + rW}{b_1}\right) \left(\frac{1 - e^{b_1(T-t_1)}}{b_1} + T - t_1\right) \right)$$

Green Repairing Cost = $g_t rW$

Total Cost = Fixed Ordering Cost + Holding Cost + Green repairing initialization technology cost + Green Repairing Cost + Incineration disposal cost + Landfilling disposal cost + Green packaging cost + Green labelling Cost + Green energy cost

$$\text{Total Cost} = C_2 + C_1 \left(\left(\frac{P-W-a_1}{b_1}\right) \left(t_1 + \frac{(e^{-b_1 t_1} - 1)}{b_1}\right) + \left(\frac{a_1 + rW}{b_1}\right) \left(\frac{1 - e^{b_1(T-t_1)}}{b_1} + T - t_1\right) \right) + G_T + g_t rW + G_{DI} + G_{DL} + G_P + g_l + G_E$$

$$\text{Total Cost} = C_2 + C_1 \left(\left(\frac{P-W-a_1}{b_1}\right) \left(t_1 + \frac{(e^{-b_1 t_1} - 1)}{b_1}\right) + \left(\frac{a_1 + rW}{b_1}\right) \left(\frac{1 - e^{b_1(T-t_1)}}{b_1} + T - t_1\right) \right) + G_T + g_t rW + j(1-r)Wg_{di} +$$

$$(1-j)(1-r)Wg_{dl} + G_P + g_l + G_E$$

$$\text{Average Cost} = \frac{\text{Total Cost}}{T}$$

$$\text{Average Cost} = \frac{\left(C_2 + C_1 \left(\left(\frac{P-W-a_1}{b_1}\right) \left(t_1 + \frac{(e^{-b_1 t_1} - 1)}{b_1}\right) + \left(\frac{a_1 + rW}{b_1}\right) \left(\frac{1 - e^{b_1(T-t_1)}}{b_1} + T - t_1\right) \right) \right) + G_T + g_t rW + j(1-r)Wg_{di} + (1-j)(1-r)Wg_{dl} + G_P + g_l + G_E}{T}$$

$$\frac{\partial TC}{\partial T} = \frac{-1}{T^2} \left(C_2 + C_1 \left(\left(\frac{P-W-a_1}{b_1}\right) \left(t_1 + \frac{e^{-b_1 t_1} - 1}{b_1}\right) \right) + G_T + g_t rW + j(1-r)Wg_{di} + (1-j)(1-r)Wg_{dl} + G_P + g_l + G_E \right) + \frac{C_1}{T^2} (a_1 + rW)(e^{-b_1 t_1} - b_1^2 T^2 e^{-b_1 t_1} - 1)$$

$$\frac{\partial TC}{\partial T} = 0$$





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$$T = \frac{1}{b_1} \sqrt{\left(\frac{C_2 + C_1 \left(\frac{P-W-a_1}{b_1} \right) \left(t_1 + \frac{e^{-b_1 t_1} - 1}{b_1} \right) + G_T + g_t rW + j(1-r)Wg_{di} +}{(1-j)(1-r)Wg_{dl} + G_P + g_l + G_E - C_1(a_1 + rW)(e^{-b_1 t_1} - 1)} \right) e^{b_1 t_1}}$$

$$T = \frac{1}{b_1} \sqrt{\frac{C_2 + C_1 \left(\frac{P-W-a_1}{b_1} \right) \left(t_1 + \frac{e^{-b_1 t_1} - 1}{b_1} \right) + G_T + g_t rW + j(1-r)Wg_{di} +}{(1-j)(1-r)Wg_{dl} + G_P + g_l + G_E - C_1(a_1 + rW)(e^{-b_1 t_1} - 1)} \frac{C_1(a_1 + rW)}{C_1(a_1 + rW)}}$$

$$\frac{\partial TC}{\partial t_1} = \frac{1}{T} \left(C_1 \left(\frac{P-W-a_1}{b_1} \right) + C_1 \left(\frac{P-W-a_1}{b_1} \right) e^{-b_1 t_1} + \frac{(a_1 + rW)}{b_1} e^{b_1 T} e^{-b_1 t_1} - \frac{(a_1 + rW)}{b_1} \right)$$

$$\frac{\partial TC}{\partial t_1} = 0$$

$$t_1 = \frac{1}{b_1} \log \left(\frac{C_1(P-W-a_1) + (a_1 + rW)e^{b_1 T}}{(a_1 + rW) - C_1(P-W-a_1)} \right)$$

Case (ii) Demand is Exponential

In this case, the demand is exponential of the form $D = a_2 e^{b_2 t}$, where a_2 is the constant term and b_2 is the growth rate of the demand.

$$\frac{dq(t)}{dt} = P - W - a_2 e^{b_2 t} \quad 0 \leq t \leq t_1 \quad (11)$$

$$\frac{dq(t)}{dt} = -(a_2 e^{b_2 t} + rW) \quad t_1 \leq t \leq T \quad (12)$$

Integrating equation (1) and (2) we get

$$q(t) = Pt - Wt - a_2 \frac{e^{b_2 t}}{b_2} + \frac{a_2}{b_2} + c \quad (13)$$

$$q(T) - q(t) = - \left(\frac{a_2}{b_2} (e^{b_2 T} - e^{b_2 t}) + rW(T - t) \right) + c \quad (14)$$

$$\text{With initial condition } q(0) = 0 \quad (15)$$

$$\text{And boundary condition } q(T) = 0 \quad (16)$$

We get $c = 0$

By (3) and (4) we get

$$q(t_1) = Pt_1 - Wt_1 - a_2 \frac{e^{b_2 t_1}}{b_2} + \frac{a_2}{b_2}$$

$$q(t) = \left(\frac{a_2}{b_2} (e^{b_2 T} - e^{b_2 t}) + rW(T - t) \right)$$

Let $q(t_1) = I_{max}$

$$Pt_1 - Wt_1 - a_2 \frac{e^{b_2 t_1}}{b_2} + \frac{a_2}{b_2} = \left(\frac{a_2}{b_2} (e^{b_2 T} - e^{b_2 t_1}) + rW(T - t_1) \right)$$

$$(P - W + rW)t + \frac{a_2}{b_2} - \frac{a_2}{b_2} e^{b_2 T} = rWT$$

By using Taylor's Series approximation

$$(P - W + rW)t + \frac{a_2}{b_2} - \frac{a_2}{b_2} (1 + b_2 T) = rWT$$

$$T = \frac{(P - W + rW)t}{b_2 - rW}$$

$$\text{Holding Cost} = C_1 \left[\int_0^{t_1} q(t) dt + \int_{t_1}^T q(t) dt \right]$$





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$$= C_1 \int_0^{t_1} \left((P - W)t - \frac{a_2}{b_2} (e^{b_2 t} - 1) \right) dt + \int_{t_1}^T \left(\frac{a_2}{b_2} (e^{b_2 T} + e^{b_2 t}) + rW(T - t) \right) dt$$

$$\text{Holding Cost} = \frac{C_1}{2} [t_1^2 (P - W) + 2 \frac{a_2}{b_2} e^{b_2 T} (T - t_1 + \frac{1}{b_2}) + 2 \frac{a_2}{b_2} t_1 + rW(T - t_1)^2]$$

Green Repairing Cost = $g_t rW$

Total Cost = Fixed Ordering Cost + Holding Cost + Green repairing initialization technology cost + Green Repairing Cost + Incineration disposal cost + Landfilling disposal cost + Green packaging cost + Green labelling Cost + Green energy cost

$$\text{Total Cost} = C_2 + \frac{C_1}{2} [t_1^2 (P - W) + 2 \frac{a_2}{b_2} e^{b_2 T} (T - t_1 + \frac{1}{b_2}) + 2 \frac{a_2}{b_2} t_1 + rW(T - t_1)^2] + G_T + g_t rW + j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E$$

$$\text{Average Cost} = \frac{\text{Total Cost}}{T}$$

$$= \frac{C_2 + \frac{C_1}{2} [t_1^2 (P - W) + 2 \frac{a_2}{b_2} e^{b_2 T} (T - t_1 + \frac{1}{b_2}) + 2 \frac{a_2}{b_2} t_1 + rW(T - t_1)^2] + G_T + g_t rW + j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E}{T}$$

$$\frac{\partial TC}{\partial T} = 0$$

$$T = \sqrt{\frac{C_2 + \frac{C_1}{2} (t_1^2 (P - W) + 2 \frac{a_2}{b_2} t_1 + rW t_1^2) + G_T + g_t rW + j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E}{C_1 a_2 (b_2 - b_2 t_1 - 1)}}$$

$$\frac{\partial TC}{\partial t_1} = 0$$

$$t_1 = \frac{2(C_1 a_2 - rWT)}{C_1 (P - W) + 2rW}$$

Case (iii) Demand is logarithmic

In this case, the demand is logarithmic of the form $D = \log(a_3 + b_3 t)$, with the constant term a_3 and the growth parameter b_3 .

$$\frac{dq(t)}{dt} = P - W - \log(a_3 + b_3 t) \quad 0 \leq t \leq t_1 \quad (17)$$

$$\frac{dq(t)}{dt} = -(\log(a_3 + b_3 t) + rW) \quad t_1 \leq t \leq T \quad (18)$$

Integrating equation (1) and (2) we get

$$\int_0^t dq(t) = \int_0^t (P - W - \log b_3 - \log(\frac{a_3}{b_3}) - \frac{b_3 t}{a_3} + \frac{b_3^2 t^2}{2a_3^2}) dt$$

$$q(t) = (P - W - \log a_3)t - \frac{b_3}{2a_3} t^2 + \frac{b_3^2 t^3}{6a_3^2} + c \quad (19)$$

$$\int_{t_1}^T dq(t) = - \int_{t_1}^T (\log(a_3 + b_3 t) + rW) dt$$

$$q(T) - q(t) = - \left[(T - t) \log b_3 + (T - t) \log \left(\frac{a_3}{b_3} \right) + \frac{b_3}{2a_3} (T^2 - t^2) - \frac{b_3^2}{2a_3^2} (T^3 - t^3) \right] + c \quad (20)$$

$$\text{With initial condition } q(0) = 0 \quad (21)$$

$$\text{And boundary condition } q(T) = 0 \quad (22)$$

We get $c = 0$

By (3) and (4) we get

$$q(t_1) = (P - W - \log a_3)t - \frac{b_3}{2a_3} t^2 + \frac{b_3^2 t^3}{6a_3^2}$$

$$q(t_1) = (T - t) \log b_3 + (T - t) \log \left(\frac{a_3}{b_3} \right) + \frac{b_3}{2a_3} (T^2 - t^2) - \frac{b_3^2}{2a_3^2} (T^3 - t^3)$$





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Let $q(t_1) = I_{max}$

$$\begin{aligned}
 I_{max} &= (P - W - \log a_3)t - \frac{b_3}{2a_3}t^2 + \frac{b_3^2t^3}{6a_3^2} \\
 I_{max} &= (T - t)\log b_3 + (T - t)\log\left(\frac{a_3}{b_3}\right) + \frac{b_3}{2a_3}(T^2 - t^2) - \frac{b_3^2}{2a_3^2}(T^3 - t^3) \\
 (P - W - \log a_3)t - \frac{b_3}{2a_3}t^2 + \frac{b_3^2t^3}{6a_3^2} &= (T - t)\log b_3 + (T - t)\log\left(\frac{a_3}{b_3}\right) + \frac{b_3}{2a_3}(T^2 - t^2) - \frac{b_3^2}{2a_3^2}(T^3 - t^3) \\
 (P - W)t_1 &= T\log a_3 \\
 T &= \frac{(P - W)t_1}{\log a_3} \quad (23)
 \end{aligned}$$

Holding Cost = $C_1[\int_0^{t_1} q(t)dt + \int_{t_1}^T q(t)dt]$

$$\begin{aligned}
 &= C_1\left(\int_0^{t_1} \left((P - W - \log a_3)t - \frac{b_3}{2a_3}t^2 + \frac{b_3^2t^3}{6a_3^2}\right)dt\right. \\
 &\quad \left.+ \int_{t_1}^T \left((T - t)\log b_3 + (T - t)\log\left(\frac{a_3}{b_3}\right) + \frac{b_3}{2a_3}(T^2 - t^2) - \frac{b_3^2}{2a_3^2}(T^3 - t^3)\right)dt\right)
 \end{aligned}$$

$$\text{Holding Cost} = C_1\left((P - W)\frac{t_1^2}{2} + \frac{T^2}{2}\log a_3 + \frac{b_3}{3a_3}T^3 - \frac{b_3^2T^4}{8a_3^2} - Tt_1\log a_3 - \frac{b_3}{2a_3}T^2t_1 + \frac{b_3^2T^3t_1}{6a_3^2}\right)$$

Green Repairing Cost = g_trW

Total Cost = Fixed Ordering Cost + Holding Cost + Green repairing initialization technology cost + Green Repairing Cost + Incineration disposal cost + Landfilling disposal cost + Green packaging cost + Green labelling Cost + Green energy cost

$$\text{Total Cost} = C_2 + C_1\left((P - W)\frac{t_1^2}{2} + \frac{T^2}{2}\log a_3 + \frac{b_3}{3a_3}T^3 - \frac{b_3^2T^4}{8a_3^2} - Tt_1\log a_3 - \frac{b_3}{2a_3}T^2t_1 + \frac{b_3^2T^3t_1}{6a_3^2}\right) + G_T + g_trW +$$

$$\begin{aligned}
 &j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E \\
 &(C_2 + C_1\left((P - W)\frac{t_1^2}{2} + \frac{T^2}{2}\log a_3 + \frac{b_3}{3a_3}T^3 - \frac{b_3^2T^4}{8a_3^2} - Tt_1\log a_3 - \frac{b_3}{2a_3}T^2t_1 + \frac{b_3^2T^3t_1}{6a_3^2}\right)
 \end{aligned}$$

$$\text{Average Cost} = \frac{+G_T + g_trW + j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E}{T}$$

$$\begin{aligned}
 \frac{\partial TC}{\partial T} &= \frac{-1}{T^2}\left(C_2 + C_1(P - W)\frac{t_1^2}{2} + G_T + g_trW + j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E\right) + C_1\left(\frac{\log a_3}{2} + \frac{2b_3T}{3a_3}\right. \\
 &\quad \left.- \frac{b_3t_1}{2a_3} + \frac{b_3^2T^3t_1}{3a_3^2}\right)
 \end{aligned}$$

$$\frac{\partial TC}{\partial T} = 0$$

$$T = \sqrt[3]{\frac{3C_1a_3^2\left(C_2 + C_1(P - W)\frac{t_1^2}{2} + G_T + g_trW + j(1 - r)Wg_{di} + (1 - j)(1 - r)Wg_{dl} + G_P + g_l + G_E\right)}{2a_3b_3 + b_3^2t_1}}$$

$$\frac{\partial TC}{\partial t_1} = \frac{1}{T}\left(C_1(t_1(P - W) - T\log a_3 - \frac{2b_3T^2}{3a_3} + \frac{b_3^2T^3}{3a_3^2}\right)$$

$$\frac{\partial TC}{\partial t_1} = 0$$

$$t_1 = \frac{T\log a_3 - \frac{b_3}{2a_3}T^2 - \frac{b_3^2T^3}{6a_3^2}}{P - W}$$

The concavity condition is satisfied by all the system of differential equations discussed under the three cases. The concavity map obtained for case (i) is presented in Fig.1.





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RESULTS AND DISCUSSION

Python programming language is used to solve the differential equations presented in the three cases namely (i), (ii) and (iii). The solution plots are presented for each of the cases in Fig.2,3 and 4 respectively. Fig.2 clearly represents the consistent nature of the solutions of the differential equations with linear demand subjected to the initial and boundary conditions. The plot exhibits a continuous and smooth transition at $t=t_1$ reflecting the efficacy of the solution. It is very evident that $q(t)$ is more influenced by the parameters W, a_1, b_1, rW . Fig.3 clearly represents the consistent nature of the solutions of the differential equations with exponential demand subjected to the initial and boundary conditions. The plot exhibits a continuous and smooth transition at $t=t_1$ from increasing to decreasing demand. It is very evident that $q(t)$ is more influenced by the parameters W, a_2, b_2, rW . Fig.4 clearly represents the consistent nature of the solutions of the differential equations with exponential demand subjected to the initial and boundary conditions. The plot exhibits a continuous and smooth transition at $t=t_1$ from increasing to decreasing demand. It is very evident that $q(t)$ is more influenced by the parameters W, a_3, b_3, rW .

Sensitivity Analysis

Case (i)

The effects of the parameters W, a_1, b_1, rW on $q(t)$ is determined by varying the parametric ranges. The following Fig.5 represents the changes in $q(t)$ with respect to the changes in the chosen parameters. The sensitivity analysis of the parameters on $q(t)$ indicates that as these parameters increase, the initial impact on $q(t)$ is positive, with all curves showing an initial rise. Higher values of the parameters result in peaks occurring later, signifying a delay in the peak effect. Post-peak, higher parametric values exhibit a more gradual decline, indicating a prolonged impact. The magnitude of the peak value increases with the parametric values, showing a greater influence on $q(t)$ at its peak. Overall, the relationship between the parameters and $q(t)$ is systematic and predictable, with higher parametric values leading to delayed, higher, and more sustained peaks in $q(t)$.

Case (ii)

The effects of the parameters W, a_2, b_2, rW on $q(t)$ is determined by varying the parametric ranges. The following Fig.6 represents the changes in $q(t)$ with respect to the changes in the chosen parameters. The sensitivity analysis of parameters affecting $q(t)$ indicates that increasing these parameters results in an initial positive impact, with all curves rising at the start. As parameter values increase, the peaks occur later, showing a delayed peak effect. Following the peak, higher parameter values lead to a more gradual decline, indicating a longer-lasting impact. The peak value's magnitude also rises with higher parameter values, showing a greater influence on $q(t)$ at its peak. In summary, the relationship between the parameters and $q(t)$ is systematic and predictable with higher parameter values result in delayed, higher, and more sustained peaks in $q(t)$.

Case (iii)

The effects of the parameters W, a_3, b_3, rW on $q(t)$ is determined by varying the parametric ranges. The following Fig.7 represents the changes in $q(t)$ with respect to the changes in the chosen parameters. The sensitivity analysis of the parameters on $q(t)$ shows that as these parameters increase, the initial effect on $q(t)$ is positive, with all curves rising initially. Higher parameter values cause the peaks to occur later, indicating a delay in the peak effect. After reaching the peak, higher values result in a more gradual decline, suggesting an extended impact. Additionally, the peak value itself increases with higher parameters, reflecting a greater influence on $q(t)$ at its peak. Overall, the relationship between the parameters and $q(t)$ is systematic and foreseeable, with increased parameter values leading to delayed, higher, and more prolonged peaks in $q(t)$.

CONCLUSION

This research work presents a comprehensive framework of production based sustainable inventory models with different demand patterns. The demand fluctuations under the influence of different parameters are analyzed. The



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sustainable inventory model proposed earlier is explored under the demand patterns of linear, exponential and logarithmic to facilitate the decision makers employ the proposed sustainable models under different decision-making circumstances. Python is utilized in solving and analyzing the system of equations under three different cases and this intervention has provided consistent results. This has facilitated to draw inferences on the parametric influences over the inventory level. This research work shall also be extended by varying the nature of the demand and a comparative analysis shall also be made across several demand patterns to derive comprehensive results.

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Table:1

Author	Year	Demand Pattern	Green Cost Parameters
Ali AlArjaniet al.[23]	2021	A Sustainable Economic Recycle Quantity Model for Imperfect Production System with Shortages	sustainable recycling
Ali Akbar Shaikh et al.[14]	2020	Ramp type demand	Generic costs
Bappa Mondal et al.[17]	2020	Logistic	Generic costs
Chayanika Rout et al.[11]	2020	Deterministic	Carbon emission costs
Subhash Chandra Das et al.[4]	2020	Dependent on the selling price of the product.	Preservation technology costs
Abolfazl Gharaei, Eman Almehdawe[8]	2021	Deterministic	Sustainability





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Abu Hashan Md Mashud et al.[24]	2021	Deterministic	Carbon emission reduction costs
Arash Sepehri et al.[13]	2021	Deterministic	Preservation technology, carbon emissions costs
Balaji Padhy et al.[27]	2021	Exponential	Generic costs
Dharmendra Yadav et al.[16]	2021	Cross-price elasticity of demand.	Sustainability, Carbon emission and preservation technology costs
Indrajitsingha et al. [1]	2021	Stock Dependent	Generic costs
Jani et al. [28]	2021	Price-Sensitive time-dependent	Generic costs
Reza Maihami et al.[25]	2021	linear function of the sales price and greenness level	Sustainability and Greening Cost
Varun Mohan et al.[7]	2021	Exponential	Cost of carbon emission, Carbon emission due to deterioration of inventory
Yosef et al[15]	2021	Deterministic	Carbon emission costs
Zheng Liu et al.[18]	2021	Deterministic	Generic costs
Bhavani, G. Durga, et al.[22]	2022	Exponential	Environmental emission reduction, deterioration, green technology
Dharmesh Katariya et al.[6]	2022	Function of selling price	Sustainable costs, Carbon emissions, green technology costs
Haripriya Barman et al.[19]	2022	Deterministic	Preservation technology, carbon cap- and -trade policy, green technology
Nita Shah et al.[2]	2022	Price-Sensitive time-dependent	Carbon Emission Cost & Green Technology Cost
Mohammad Reza Gholamian Maryam Noroozi[20]	2022	Deterministic	Green technology investment
Chaman Singh Gurudatt Rao Ambedkar[12]	2023	Stock selling cost and lifetime dependent demand	Generic costs
Hui-Ling Yang[26]	2023	Linear demand	Generic costs
Magfura Pervin et al.[10]	2023	Composite demand Linear demand Exponential demand	Sustainable inventory model, carbon emission and environmental impact
S. Loganayaki et al.[9]	2024	Deterministic	Preservation technology cost
MakoenaSebatjane[3]	2024	Deterministic	Carbon emissions reduction, Sustainable costs
Muthusamy Palanivel et al.[5]	2024	Ramp-type demand	Carbon emission, Green technology costs
S.Ramya and D.Sivakumar[21]	2024	Exponential	Generic costs
Theeba A and Nivetha Martin[29]	2024	Deterministic	Sustainable costs



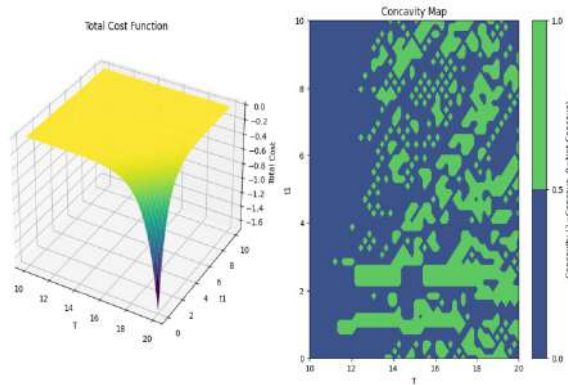


Fig.1 represents that theconcavity depends on the optimal values of t_1 and T and this is due to the inclusion of several cost components in the modelling framework.

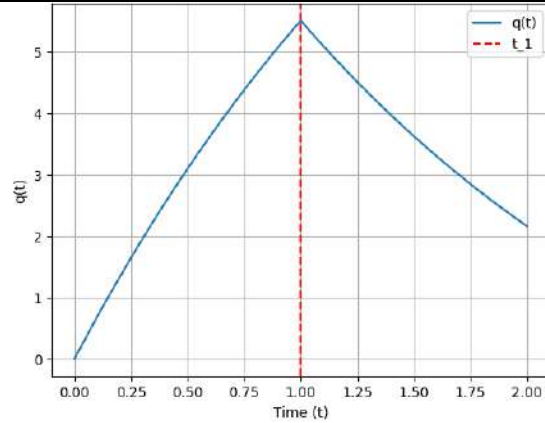


Fig. 2 Solution of the Differential Equation with Linear Demand

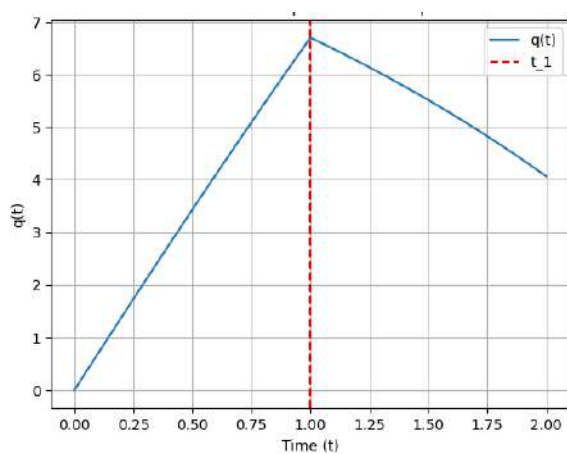


Fig.3 Solution of the Differential Equation with Exponential Demand

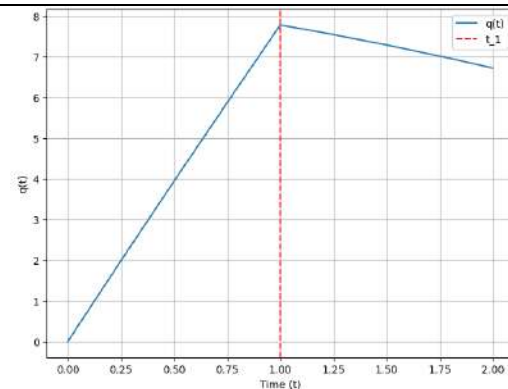


Fig.4 Solution of the Differential Equation with Logarithmic Demand





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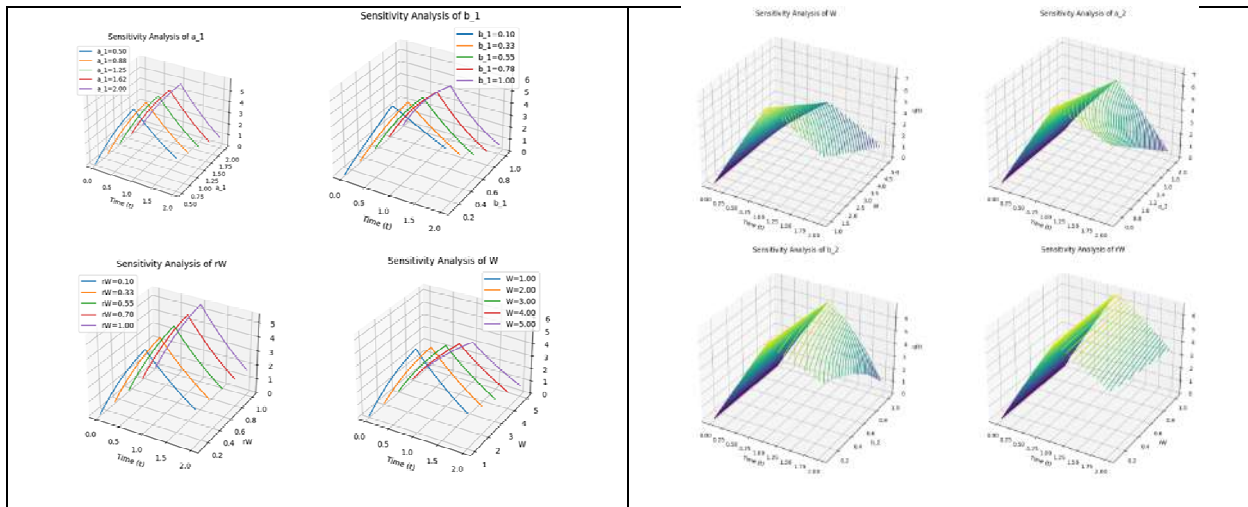


Fig. 5 Sensitivity Analysis of Parameters under Case (i)

Fig. 6 Sensitivity Analysis of Parameters under Case (ii)

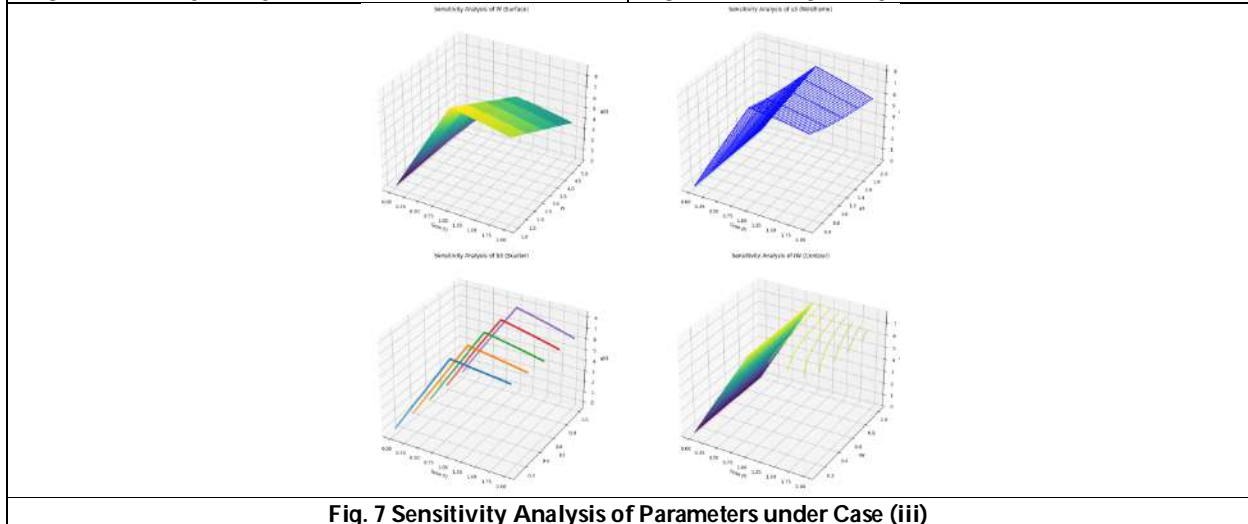


Fig. 7 Sensitivity Analysis of Parameters under Case (iii)





Molecular Docking Studies of Phytoconstituents from Seeds of *Syzygium cumini* as Potential Inhibitors of Targets of Diabetes Mellitus

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ABSTRACT

Jamun or Indian black berry is obtained from *Eugenia jambolana*, synonymously known as *Syzygiumcumini Lam.* of family Myrtaceae. It is commonly found all over the India. From the ancient era, it has been considered as traditional plant for the treatment of various diseases. Seeds in particular are widely used as an antidiabetic remedy in traditional system of medicine. To comprehend more about antidiabeticproperties of seeds, atotal 66 phytoconstituents of *Syzygiumcumini Lam. seeds* were used inmolecular docking studies using four targets of diabetes namely human peroxisome proliferator activated receptor- γ , Dipeptidyl peptidase-4, AMP-activated protein kinase and sodium glucose co-transporter-2. The docking studies were carried out using PyRx and AutoDock 1.5.6 software. Compound with better binding affinity were subjected to evaluate drug likeliness and toxicity using SwissADME and admetSARtools. Ellagitannin ($-10.4 \text{ kcal mol}^{-1}$) and Corilagin ($-9.2 \text{ kcal mol}^{-1}$) has better binding affinity with Dipeptidyl peptidase as compared to Sitagliptin ($-7.9 \text{ Kcal mol}^{-1}$). Quercetin (-8.7kcal mol^{-1}), Ellagic acid($-8.2 \text{ Kcal mol}^{-1}$) and Pinoresinol ($-8.8 \text{ kcal mol}^{-1}$) were found to have more affinity with Sodium Glucose Cotransporter-2. Ellagitannin ($-8.8 \text{ kcal mol}^{-1}$) and Maslinicacid ($-8.7 \text{ kcal mol}^{-1}$) has better binding affinity with AMP- activated protein kinase as compared to Metformin (-3.8kcal mol^{-1}). Rosiglitazone ($-9.9 \text{ kcal mol}^{-1}$) was found to bind better with Human peroxisome proliferator-activated receptor as compared to others.Further *in-vitro* and *in-vivo* studies are essential to confirm the use of Ellagitannin, Corilagin, Ellagic acid, Pinoresinol, Quercetin, Epoxidecanoic acid and Malvalic acid as an antidiabetic agent.



**Bhaghyashri Adalinge et al.,****Keywords:** *Syzygiumcumini*, diabetes mellitus, molecular docking, PPAR, dipeptidyl peptidase-4, SGLT-2, AMPK.

INTRODUCTION

Diabetes mellitus (DMT) is group of metabolic disorders, sharing common underlying features of hyperglycaemia. Worldwide, more than 140 million peoples are suffering from it. It occurs as a defect in insulin, insulin action or both. The chronic hyperglycaemia and associated metabolic disregrulationare associated with secondary damage to multiple organ system, especially the kidney, eye, nerve and blood vessels. DMT type IIhas caused various concerns over the years due to cost and side effects arising from long term use of current treatment(Kumar, 2020).Jamun or Indian black berry is obtained from *Eugenia jambolana* synonymously known as *Syzygiumcumini* Lam(Rauf, 2016). of family Myrtaceae. It is commonly found in all over the India(Ahmed, 1991). From the ancient era, it has been considered as traditional plant for the treatment of various diseases. It possesses activities like antidiabetic, anti-inflammatory, anticancer etc. The fruits, seeds, leaves, bark and extracts of this plant play an important role in the treatment of different disorders as reported in different experimental works carried out by many researchers(Anonymous, 1996).There are certain reports which specify the antidiabetic activity for particular phytoconstituents of the seeds of *S. cumini* in treatment of DMT (Kerru, 2018). The current study is aimed towards molecular docking to access the potential phytochemicals of *Syzygium* plant as an inhibitor or stimulator of various targets of DMT-II in comparison to marketed drugs. Study was further continued to check drug likeliness and toxicity parameters.

MATERIALS AND METHODS

Construction of phytoconstituents library

A library of phytoconstituents of the seeds of *Syzygiumcumini* was constructed from Indian Medicinal Plants, Phytochemistry and Therapeutic (IMPPAT) database and literature survey (Table 1). The structures of ligands, inhibitor or activator were downloaded from Pubchem in SDF format. PyMol was used to covert SDF files to PDB format(pymol, 2024).

Selection of molecular targets and molecular docking analysis

Molecular docking study was conducted by using PyRx and AutoDock 1.5.6 software(Trott, 2024). The X-ray crystal structure of receptors like Dipeptidyl peptidase-IV (DPP-4, PDB ID: 4FFW, resolution: 2.90Å⁰) with Sitagliptin as co-crystallized ligand, human peroxisome proliferator activated receptor- γ (PPAR- γ , PDB ID: 4EMA, resolution: 2.54Å⁰) with Rosiglitazone, Sodium Glucose Cotransporter-2 (SGLT-2, PDB ID: 7VSI, resolution: 2.95 Å⁰) with Empagliflozin, AMP- activated protein kinase (AMPK, PDB ID: 4CFE, resolution: 3.02Å⁰) in complex withbenzimidazole derivatives were taken from RCSB PDB database. Virtual screening of all targets was performed by molecular docking into active site of each receptor by using PyRx software. The targets were again docked with phytoconstituents having optimum binding affinity using AutoDock 1.5.6. Steps involved in protein preparation are removal of water molecules, addition of Kollaman charges and only polar hydrogens.

Coordinates of grid boxes used in molecular docking:

The X, Y, and Z co-ordinates for PPAR- γ receptor are 13.61, 6.22 and 37.66 respectively. Rosiglitazone is found to exert its action by activating this receptor. The DPP-4 is inhibited with Sitagliptin atX, Y, and Z co-ordinates of 19.54, -11.29 and 51.85 respectively. Similarly, SGLT-2 has X, Y, and Z co-ordinates of 37.44, 48.47 and 43.67 respectively with Empagliflozin as an inhibitor. For AMPK, these are 477.6, 41.06 and 987.04 respectively. Metformin is widely used for the treatment of DMT-II. It is potent agent having significant sugar lowering capacity.The locations of binding sites were decided based on the actual pose of inhibitor and/ activator. The size of the grid box was adjusted to 40 Å⁰. The saved poses of complexes were assessed by using Discovery studio visualizer (version 24.1.0.23298)



**Drug likeliness and ADMET studies**

Apart from the appropriate binding affinity, the phytochemicals should have desirable pharmacokinetic and pharmacodynamics properties. These were further studied by drug likeliness parameter by using Swiss ADME online web tool. The ADMET profile of shortlisted phytochemicals were also studied using Admet SAR.

RESULT AND DISCUSSION**Construction of phytochemical library**

The goal of this study was identifying the constituents of *S.cumini* that may have antidiabetic property. Hence, all phytoconstituent reported in the literature and from IMPPAT database were considered for docking. The binding score of all listed phytoconstituents are given in Table 2.

Docking Studies**Dipeptidyl peptidase (DPP-4, 4FFW)**

It is a serine exopeptidase with 766 amino acid distributed widely in numerous tissues such as kidney, spleen, liver, intestine, placenta, lymphocytes, adrenal glands, and endothelial cells. The incretins (GLP-1 and GIP) are the substrates of DPP IV. Sitagliptin exerts its antidiabetic action by inhibiting this enzyme. The binding energies of Ellagitannin, Corilagin and Maslinic acid to this receptor were -10.4, -9.2, -8.8 Kcalmol⁻¹ respectively. Ellagitannin was found to bind more favourably than Sitagliptin with chain A with interactions through Tyr 663, Tyr667, Tyr558, Arg123, Ser 552, Gln554, Gly207 and Phe355. The binding interactions involved Conventional Hydrogen bond, Pi-Pi stacked, Pi-Pi T shaped and Carbon Hydrogen bond. The structure of DPP-4 and protein-ligand interactions of selected ligands are shown in Fig 1.

Sodium Glucose Co-Transporter 2(SGLT-2)

Chain A was considered for docking as Empagliflozine found in complex with it. The binding energies of Ellagic acid, Pinorelinol, Quercetin and Ellagitannin which having binding affinity to receptor [-8.2, -8.8, -8.7, -10.8 Kcal.mol⁻¹] respectively. Ellagic acid was found to bind more favourably than Empagliflozine. Ellagic acid formed Conventional Hydrogen bonds, pi-alkyl and pi-sigma bonding with involvement of ASP A:454, SER A: 508 amino acids. Also involved vander waal forces and weak interaction with amino acids. The structure of SGLT-2 and protein-ligand interactions of selected ligands are shown in Fig 2.

AMP-activated protein kinase(AMPK)

Metformin, an AMPK agonist gives activity by inhibiting the hepatic gluconeogenesis and oppose the action of glucagon. AMPK activators mimic the action of insulin. The binding energies of Ellagitannin, Maslinic acid, Betulinic acid, Allo-Aromandrene and Quercetin to this receptor were -8.8, -8.7, -8.0, -7.5 -7.0Kcalmol⁻¹ respectively. The various interactions of Metformin were through conventional hydrogen bonding with amino acids Ser E 144, Cys E 131, Asp E 140. Ellagitannin shows interaction with receptor by conventional hydrogen bonding and van der Waals forces. Ellagitannin was found to be the most promising molecule with highly stable complex formation with involvement of Arg-B 83, Asn-A: 48, Thr-A: 83 via Conventional Hydrogen bonding and Hydrophobic Alkyl bonding. The structure of receptor and 2-D binding interactions of receptor with ligands is shown in Fig. 3.

Human peroxisome proliferator-activated receptor (PPAR- γ)

PPAR- γ inhibition is considered as the potential therapeutic route in treatment of DMT-II. It is commonly known as Type II nuclear receptor majorly found in adipose tissue. It enhances the glucose metabolism by activation of insulin sensitivity to the receptors(Md.Rashedul Alam, 2012). It also regulates adipogenesis. Thiazolidinediones like Rosiglitazone, Pioglitazone, Troglitazone etc are the examples of drugs which mainly target this receptor(Tambe, 2024). The binding energies of Epoxidecanoic acid, Linoleic acid, Malvalic acid, Sterculic acid and Oleic acid to this receptor were -5.5, -5.0, -4.8, -4.7 and -4.4 Kcal mol⁻¹ respectively. Epoxidecanoic acid shown highest binding affinity towards the receptor with the involvement of the Leu A: 400, Gly A: 399, Val A: 332, Val A: 403, and Lys B: 373 amino



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acids by forming conventional hydrogen bonding and Vander Waal forces. Epoxidecanoic acid has less binding score as compared to marketed Rosiglitazone. Rosiglitazone has formed pi-pi T shaped, amide pi stacked and pi-sigma bonding with the protein. The structure of PPAR- γ and protein-ligand interactions of selected ligands are shown in Fig 4.

Pharmacological and toxicological properties of the ligand

The results of drug likeliness parameter and ADMET parameters are represented in the Table 3 and Table 4 respectively. Lipinski rule of five was studied to check the physiochemical properties and drug ability of phytoconstituents. Epoxidecanoic acid and Ellagic acid have good oral bioavailability while Ellagitannin have shown three Lipinski violations. All compounds are non-carcinogenic and non-toxic can be further used for the treatment of DMT-II in human. The predicted toxicological properties of phytoconstituents using admetSAR tool informed that molecules were non-Amestoxic.

CONCLUSION

This study has laid emphasis on screening of 66 phytochemicals from *S.cumini* as inhibitors of DPP4 (4FFW), PPAR- γ (4EMA), SGLT-2 (7VSI), and AMPK (4CFE) using PyRx software. From the results, it can be concluded that Ellagitannin ($-10.4 \text{ kcal.mol}^{-1}$) and Corilagin ($-9.2 \text{ kcal.mol}^{-1}$) has better binding affinity with DPP4 as compared to Sitagliptin while Quercetin ($-8.7 \text{ kcal.mol}^{-1}$), Ellagic acid ($-8.2 \text{ kcal.mol}^{-1}$) and Pinorensin ($-8.8 \text{ kcal.mol}^{-1}$) are better fit candidates for SGLT-2 as compared to Empagliflozin. Ellagitannin ($-8.8 \text{ kcal.mol}^{-1}$) and Maslinic Acid ($-8.7 \text{ kcal.mol}^{-1}$) has better binding affinity with AMPK as compared to Metformin. The selected phytoconstituents were also found to be bioavailable based on in-silico screening. Further *invitro* and *in vivo* studies are essential to confirm the use of Ellagitannin, Corilagin, Ellagic acid, Pinorensin, Quercetin, Epoxidecanoic acid and Malvalic acid as an antidiabetic agent.

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Table.1: Phytoconstituents library of *S.cumini* with IMPPAT ID

No	Phytoconstituents	IMPPAT ID	No	Phytoconstituents	IMPPAT ID
1.	(-)-Globulol	IMPHY014690	35.	Humulene	IMPHY011761
2.	(+)-alpha-Cadinene	IMPHY011660	36.	Isoterpinolene	IMPHY009871
3.	(+)-delta-Cadinene	IMPHY011957	37.	Lauric acid	IMPHY009871
4.	(+)-gamma-Cadinene	IMPHY01179	38.	Limonene	IMPHY014988
5.	(+)-gamma-Gurjunene	IMPHY003956	39.	Linoleic acid	IMPHY014990
6.	1,2-Dimethoxybenzene	IMPHY006840	40.	Lupeol	IMPHY012473
7.	1-Triacontanol	IMPHY006558	41.	Malvalic Acid	IMPHY001097
8.	Allo-Aromadendrene	IMPHY016012	42.	Maslinic acid	IMPHY011970
9.	alpha-Calacorene	IMPHY013080	43.	Mesitylene	IMPHY012088
10.	alpha-Copaene	IMPHY015123	44.	Myrcene	IMPHY003485
11.	alpha-Muuroiene	IMPHY011659	45.	Myristic Acid	IMPHY000060
12.	alpha-Muuroiol	IMPHY015016	46.	Oleic acid	IMPHY011797
13.	alpha-Pinene	IMPHY012061	47.	Palmitic acid	IMPHY007327
14.	alpha-Selinene	IMPHY011581	48.	p-Cymene	IMPHY006145
15.	Aromadendrene	IMPHY014817	49.	Pinoresinol, 4-O-beta-D-glucopyranoside	IMPHY000761
16.	beta-Copaene	IMPHY003719	50.	Quercetine	IMPHY004619
17.	beta-Pinene	IMPHY012147	51.	Resorcinol	IMPHY004665
18.	beta-Sitosterol	IMPHY014836	52.	Stearic acid	IMPHY004631
19.	Betulinic acid	IMPHY012003	53.	Sterculic acid	IMPHY009570
20.	Caffeic acid	IMPHY011933	54.	Tannic acid	IMPHY011741
21.	Camphene	IMPHY014852	55.	Sitagliptin	Pubchem ID :4369359
22.	Caryophyllene oxide	IMPHY012667	56.	Metformin	Pubchem ID :4091



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23.	Caryophyllenyl alcohol	IMPHY009770	57.	Empagliflozin	PubchemID:11949646
24.	Corilagin	IMPHY010965	58.	Rosiglitazone	Pubchem ID:77999
25.	Dihydrodehydrodicony feryl alcohol	IMPHY003007	59.	(9Z)-(12S,13R)-12,13- Epoxyoctadecenoic acid	IMPHY011724
26.	Ellagic Acid	IMPHY005537	60.	(E)-2-epi-beta- caryophyllene	IMPHY014785
27.	Ellagitannin	IMPHY002419	61.	(S,1Z,6Z)-8-Isopropyl-1- methyl-5- methylenecyclodeca-1,6- diene	IMPHY011586
28.	epi-Cubenol	IMPHY013971	62.	1-(2-Hydroxy-4,6- dimethoxy-3- methylphenyl)ethan-1-one	IMPHY011359
29.	Ethyl Benzoate	IMPHY006574	63.	2-((3,3-Dimethyloxiran-2- yl)methyl)-3-methylfuran	IMPHY009211
30.	Eucarvone	IMPHY009966	64.	4-Methylbenzaldehyde	IMPHY006026
31.	Ferulic acid	IMPHY011802	65.	5 Hydroxymethyl furfural	IMPHY003174
32.	Gallic acid	IMPHY012021	66.	14-Hydroxy-9-epi-(E)- caryophyllene	IMPHY013574
33.	Gamma Terpineol	IMPHY001816	67.	14-Hydroxy-alpha- humulene	IMPHY015168
34.	Guaiacol	IMPHY011409	68.	14-Hydroxy-z- caryophyllene	IMPHY017920

Table.2: Binding energies of different phytochemicals with selected ligand using PyRx

Sr.No	Ligand (Phytoconstituents)	Binding energy (Kcal.mol ⁻¹)			
		4EMA	7VSI	4CFE	4FFW
1.	Rosiglitazone	-9.9	-	-	-
2.	Metformin	-	-	-3.8	-
3.	Sitagliptin	-	-	-	-7.9
4.	Empagliflozin	-	-9.9	-	-
5.	12,13-Epoxyoctadecenoic acid	-7.2	-7.5	-5.9	-5.7
6.	Linoleic acid	-7.1	-7.2	-5.6	-4.7
7.	MalvalicAcid	-6.9	-6.8	-5.8	-5.1
8.	Sterculicacid	-6.9	-7	-5.4	-5.2
9.	Oleic acid	-6.8	-6.8	-5.6	-5.5
10.	Palmitic acid	-6.4	-6.1	-5.2	-5.2
11.	SteraricAcid	-6.3	-6.5	-4.4	-4.7
12.	Ferulic acid	-6.2	-7.4	-6.4	-6
13.	Myristic Acid	-6.2	-6.2	-4.2	-5
14.	alpha-Copaene	-5.9	-8.1	-6.2	-5.9
15.	Ethyl Benzoate	-5.8	-6.3	-5.7	-5.1
16.	Lauric acid	-5.8	-5.9	-6.3	-4.7
17.	Limonene	-5.7	-6.3	-6.3	-4.8
18.	p-Cymene	-5.7	-6.5	-5.8	-4.8
19.	Eucarvone	-5.5	-7.4	-5.9	-5.1
20.	3-(Dimethyloxiran-2-yl) methyl)- 3-methylfuran	-5.5	-6.6	-5.6	-5.5



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21.	Guaiacol	-5.3	-8.6	-5.1	-4.8
22.	γTerpinol	-5.2	-6.7	-6.1	-5.5
23.	Isoterpinolene	-5.1	-6.5	-5.6	-5.3
24.	Myrecene	-5.1	-5.6	-5.2	-4.9
25.	4-Methylbenzaldehyde	-5	-6.4	-5.8	-4.9
26.	Gallic acid	-5	-7.1	-5.6	-5.9
27.	beta-Copaene	-5	-8.2	-6.4	-6.5
28.	1,2-Dimethoxybenzene	-5	-5.5	-5.4	-4.6
29.	(+)-delta-Cadinene	-4.9	-8.6	-7.9	-6.5
30.	5-Hydroxy Methyl Furfural	-4.9	-5.5	-4.4	-4.7
31.	Guaiol	-4.9	-8.6	-7.1	-6.1
32.	Resorcinol	-4.8	-5.6	-5.2	-5.1
33.	alpha-Selinene	-4.6	-8.4	-6.5	-6.5
34.	(+)-γ-Gurjunene	-4.5	-7.9	-7.9	-6.3
35.	Camphene	-4.5	-6.4	-5.3	-4.4
36.	alpha-Pinene	-4.4	-6.2	-6	-4.7
37.	beta-Pinene	-4.4	-6.2	-5.8	-4.6
38.	Aromadendrene	-4.1	-8	-7.9	-6.3
39.	Mesitylene	-3.9	-6.4	-5.6	-4.8
40.	1-(2-Hydroxy-4,6-dimethoxy-3-methylphenyl)ethan-1-one	-3.7	-7.4	-5.9	-5.6
41.	(+)-alpha-Cadinene	-3.6	-7.7	-7.8	-6.4
42.	alpha-Muurolol	-3.6	-7.7	-6.1	-6
43.	(+)-γ-Cadinene	-3.4	-8.1	-7.6	-6.8
44.	alpha-Calacorene	-3.3	-8.3	-7.3	-3.3
45.	alpha-Muurolene	-3.1	-7.6	-6.3	-6.2
46.	Quercetin	-3	-9.6	-8.7	-7.6
47.	epi-Cubenol	-2.8	-7.4	-5.9	-6.5
48.	14-Hydroxy-9-epi-(E)-caryophyllene	-2.3	-7.6	-6.4	-6
49.	Allo-Aromadendrene	-2.1	-8	-8	-5.9
50.	Caryophyllenylalcohol	-1.9	-8.6	-7.5	-6.3
51.	1-Triacontanol	-1.8	-7.2	-5.1	-4.5
52.	(E)-2-epi-beta-caryophyllene	-1.5	-7.8	-6.7	-6.3
53.	14-Hydroxy-γ-caryophyllene	-1.5	-7.7	-7.4	-6.1
54.	(-)-Globulol	-1.2	-7.7	-6.4	-6.5
55.	(S,1Z,6Z)-8-Isopropyl-1-methyl-5-methylenecyclodeca-1,6-diene	-1	-7.6	-	-
56.	Ellagic Acid	-0.6	-10.5	-7.6	-7.3
57.	14-Hydroxy-alpha-humulene	-0.2	-7.6	-5.9	-6.2
58.	Caryophyllene oxide	0.1	-7.5	-5.9	-6
59.	Dihydrodehydrodiconyfenyl	0.7	-8.7	-7.6	-7.2
60.	Humulene	0.8	-7.6	-5.9	-5.7
61.	Humulene epoxide II	1.2	-7.8	-5.7	-5.9
62.	beta-Sitosterol	2.5	-9.3	-6.3	-8.4
63.	Pinoresinol	3	-10.2	-8	-8.8
64.	Lupeol	17	-6.9	-7.3	-9
65.	Maslinic acid	19.6	-7.6	-8	-8.8



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66.	Betulinicacid	20.8	-7.2	-8.2	-8.5
67.	Corilagin	37.6	-8.3	-7.9	-9.4
68.	Tannic acid	106.4	-5.5	106.4	-4.2
69.	Ellagitannic Acid	135.5	-9.3	-8.7	-9.6

Table.3: Drug likeliness parameter of selected ligands

Parameter (ideal value)	Epoxidecanoic Acid	Ellagitannin	Ellagic acid
Molecular Formula	C ₁₈ H ₃₂ O ₃	C ₄₄ H ₃₂ O ₂₇	C ₁₄ H ₆ O ₈
Molecular Weight (g/mol ⁻¹) (<500)	296.44 g/mol	992.71 g/mol	302.19 g/mol
No. of H-bond acceptor (<10)	3	27	4
No. of H-bond donor (<5)	1	13	8
Log P o/w (iLOGP) (≤ 5)	4.08	1.29	0.79
Lipinski Violation (≤ 1)	0	3	0
Molar Refractivity	88.91	221.56	75.31
Bioavailability Score	0.55	0.17	0.55
Topological polar surface area A (≤140)	49.83 A ²	447.09 A ²	141.34 A ²
Number of rotatable bonds (<10)	14	5	0

Table.4: Toxicological characteristics of selected ligand

Parameter	Epoxidecanoic acid	Ellagitannin	Ellagic acid
Absorption			
Aqueous solubility (Logs)	-3.8261	-3.1958	-3.1440
Permeability in Caco-2 (Log. Papp, cm/s)	1.2563	-0.4526	-0.0760
P-glycoprotein substrate	S (0.8287)	S (0.8287)	S (0.5382)
Caco-2 permeability	Caco2+ (0.6558)	Caco2- (0.8031)	Caco2- (0.8307)
Human intestinal absorption	HIA+ (0.9937)	HIA+ (0.8930)	HIA+ (0.7199)
Blood-brain barrier	BBB+ (0.9265)	BBB- (0.6212)	BBB+ (0.5641)
Metabolism			
CYP450 2C9 Substrate	NOS (0.7601)	NOS (0.8419)	NOS (0.8339)
CYP450 2D6 Substrate	NOS (0.8652)	NOS (0.8681)	NOS (0.9096)
CYP450 3A4 Substrate	NOS (0.6059)	S (0.5504)	NOS (0.7205)
CYP450 1A2 Inhibitor	NOI (0.5957)	NOI (0.7344)	NOI (0.5914)
CYP450 2C9 Inhibitor	NOI (0.8240)	NOI (0.5940)	NOI (0.5591)
CYP450 2D6 Inhibitor	NOI (0.9390)	NOI (0.8564)	NOI (0.9575)
CYP450 2C19 Inhibitor	NOI (0.7613)	NOI (0.6821)	NOI (0.8017)
CYP450 3A4 Inhibitor	NOI (0.7256)	NOI (0.8445)	NOI (0.9078)
CYP Inhibitory Promiscuity	Low (0.9206)	Low (0.7364)	Low (0.9568)
P-glycoprotein inhibitor	NOI (0.8818)	NOI (0.9533)	NOI (0.9639)
Toxicity			
Inhibition of ether-a-go-go-related gene (Human)	WI (0.9185)	WI (0.9657)	WI (0.9721)
	NOI (0.9107)	NOI (0.7326)	NOI (0.9152)
AMES toxicity	NAT (0.9077)	NAT (0.6290)	NAT (0.9127)
Carcinogenic	NOC (0.8539)	NOC (0.9680)	NOC (0.9582)
Acute oral toxicity	III	III	II

NOS: Nonsubstrate; S: Substrate; WI: Weak inhibitor; NOI: Non-inhibitor; I: Inhibitor; NOC: Non-carcinogenic; NAT: Non-Ames toxic; AT: Ames toxic



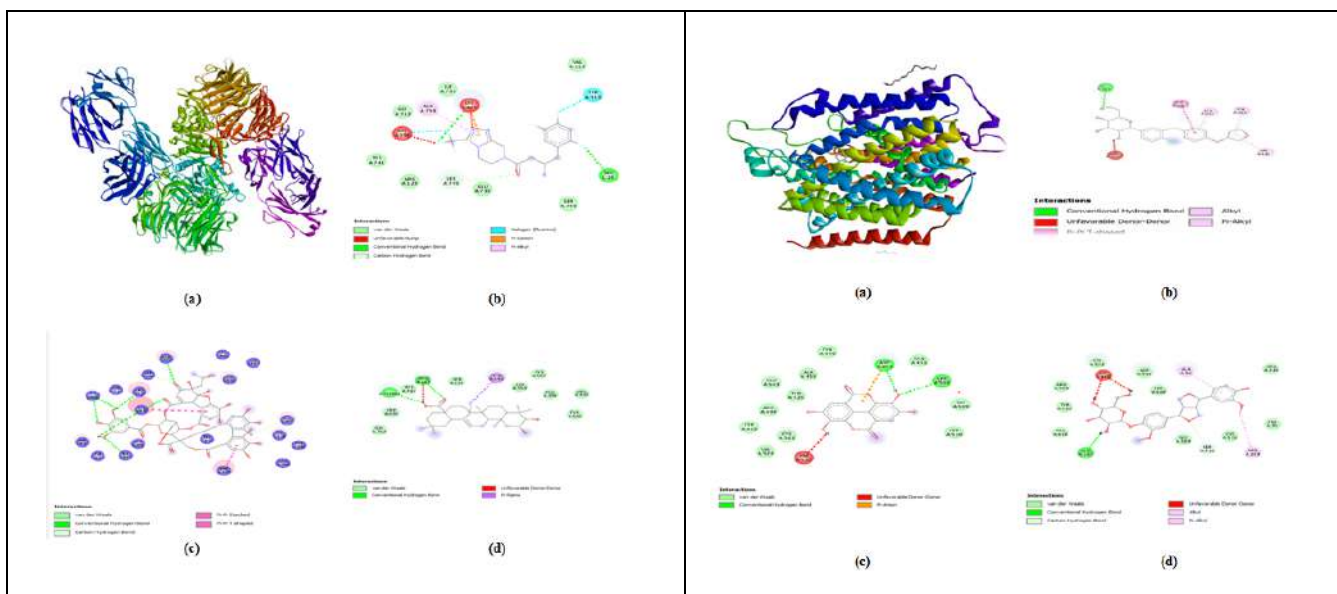


Figure 1: (a)Structure of DDP4, (b) Protein ligand interaction of DPP-4 with Sitagliptin, (c)Ellagitannin, and (d) Maslinic acid

Figure.2: (a) Structure of SGLT-2, (b)Protein ligand interaction of SGLT- 2 with Empagliflozin, (c) Ellagic acid and (d) Pinoresinol

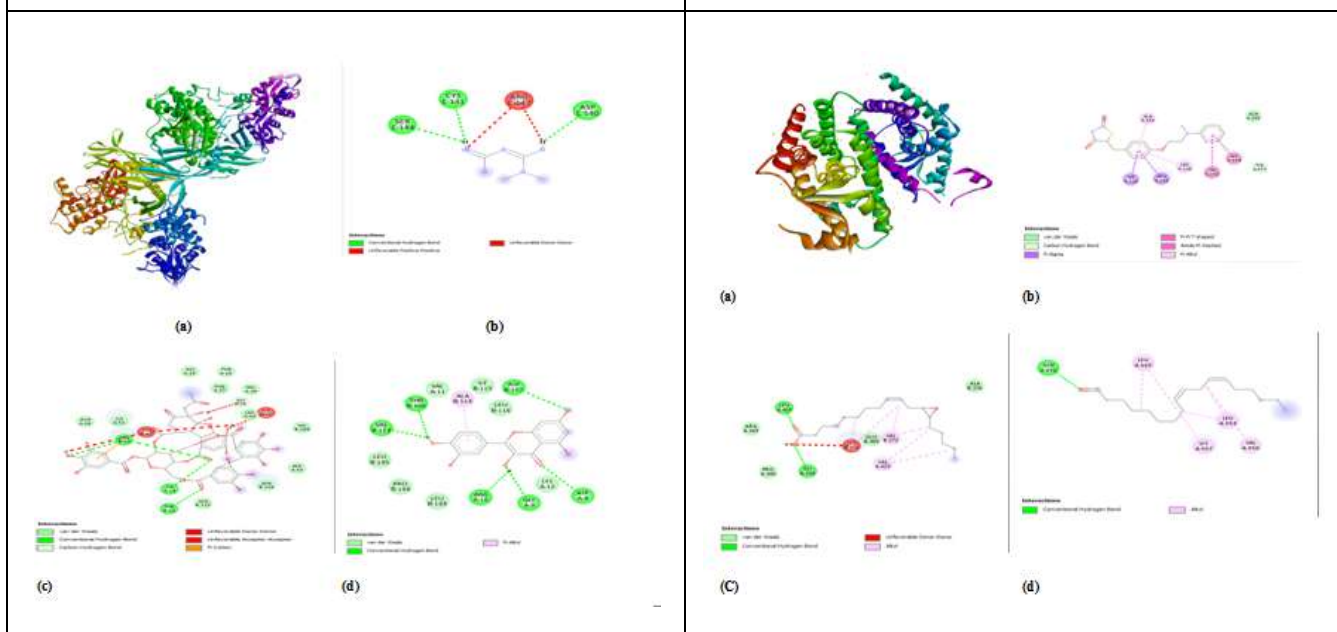


FIG 3. a) Structure of AMPK receptor, (b) Protein ligand interaction ofAMP-activated protein kinase (AMPK) with Metformin, (c) Ellagitannin and (d) Quercetin

FIG 4.(a)Structure of PPAR- γ (b) Protein ligand interaction ofPPAR- γ with Rosiglitazone, (c) Epoxidecanoic acid and(d) Linoleic acid





Analysis of Organizational Culture on Gender Equality in Promotions - A Quantitative Study

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ABSTRACT

This research explores gender equity in workplace promotions by analyzing how organizational culture, leadership styles, communication systems, and reward policies influence promotional practices. It identifies key barriers hindering women's career progression, focusing on variables like leadership perception, communication inclusivity, reward fairness, stress levels, support satisfaction, and promotion satisfaction. The study highlights that biased leadership practices, communication norms, and reward systems perpetuate gender differences, leaving women underrepresented in leadership roles. Proposed solutions include inclusive leadership training, equitable reward practices, and open communication systems to promote gender parity in the workplace.

Keywords: Gender Equality, Leadership Styles, Open Communication System, Organizational Culture, Promotions

INTRODUCTION

Gender has remained a stubborn problem in promotions even where establishments have started providing equal employment opportunities. Organizational culture assumes the role of determining promotion, given that it encompasses leadership promotion, communication procedures and reward patterns that define the employee's growth. Although, without difference in qualification documents and performance, women are found to suffer from various social barriers which do not let them arise to higher level of management. As such, this research seeks to investigate how organizational culture, including leadership, communication and reward system, either perpetuates



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or subsequent gender inequality in promotions. Also, it will evaluate measures for diversity and inclusion and how they enhance the gender equity in the workplace setting.

LITERATURE REVIEW

The competitive landscape intensifies expectations for service quality, adding to workplace stress for employees. This highlights the need for effective stress management strategies in the sector (Karthikeyan et al.). The study research emphasizes the need for stress management interventions at both individual and organizational levels to improve health, interpersonal relationships, and overall job performance in the healthcare sector (Nisa et al., 2024). Occupational exposure causes greater anxiety than community exposure, highlighting the need for workplace safety measures to mitigate fear and protect mental health. (Muthuswamy & Nithya, 2023), Data collected from employees reveal significant correlations between these security measures and digital workplace effectiveness, providing valuable insights for policymakers to develop strategies that strengthen cyber security (Muthuswamy & Nithya, 2023). The authors suggest targeted interventions, including inclusive recruitment and leadership development programs, to foster equitable workplaces and improve organizational performance (Xalxo, Seema, 2024). Many authors have focused on the role of organizational culture in gender equality with concerns to promotions. Promotion prospects have been cited many times as one of the leadership types to affect career paths. In view of its stress on effectiveness and goal accomplishment, transactional leadership is likely to appeal to assertive workers, who are preferentially male, thereby locking out women from promotions (Eagly, 2007). While mentoring and growing the employees through transformational leadership where leaders encourage more subordinates to apply for such positions, succession practices contain prejudice though providing more openings for diverse subordinate membership. Even within organizations, there are communication standards that serve to enhance monopoly or subjugation of women. But a hierarchical organizational communication structure that locates women at the lower levels of the organizational structures makes it difficult for their inputs to reach the top levels (Powell & Graves, 2003). Another structural source of career self-management is informal networks, which are particularly masculinized, so that important information and opportunities are more readily available to male employees (Ibarra, 1993). It is therefore quite possible that while the reward systems are performance based, they are still gender biased. The leaders and risk-takers are most times male while females are under rewarded because they are encouraged to collaborate, nurture and build teams (Cohen & Gagnon, 1993). Research has revealed that women are paid less compared to men and more so, when they perform well, they receive little or no commendation at all, this goes hand in hand with the fact that most supervising and managers prefer their subordinates and direct reports to be risk-takers, and work independently (Moss-Racusin et al., 2012). Based on these factors, various organizations have introduced diversity and inclusion policies that support the cause of gender diversity. But the results of these programs suggest that they barely touch on the underlying cultural causes of the gender bias (Kalev et al., 2006). Though some organizations have made some achievements, most of them still encounter major difficulties in promoting women to senior management positions.

OBJECTIVES OF THE STUDY

1. To analyze the impact of organizational culture, leadership styles, and communication norms on gender equality in promotions.
2. To evaluate the fairness of reward systems in advancing women to leadership roles.
3. To identify barriers to women's career progression and recommend strategies for a gender-equal workplace.

METHODOLOGY

This study adopts a quantitative research design, employing analytical research design to explore how organizational culture influences gender equality in promotions.



**Anjani****SAMPLE SIZE AND SAMPLING TECHNIQUE**

The respondents were 200 employees, of which 100 were men and 100 women; questionnaires about leadership, communication, and rewards were administered on the respondents and interviews conducted on them. The participants were purposively recruited in the organization to ensure that they appreciated the phenomena being studied and had experience in the organization.

DATA COLLECTION TOOLS AND DATA ANALYSIS

Information was gathered from structured interviews, in which participants could give their direct message about the event or situation. For data analysis, inferential statistics and correlation analysis was used in a bid to test relationships between variables. Some of the important links were between leadership behavior with gender equity, between communication openness and promotion opportunity, between reward policy and employee pressure. It meant that the study was getting an insight into organizational practices concerning gendered promotions.

MAJOR FINDINGS

The above Table 1.1 implies that from this demographic data, the age distribution and experience of the male and female employees is almost equivalent. The percentage distribution of recruits by age and gender is as follows: 25–30: 20%; 31–35 and around 30%; 36–40: 20%; 41–45: 15%; above 46: 15%. Again, work experience has been proven to be the same at 25% with 0–5 years, 35% with 6–10 years, 20% with 11–15 years and 10% each with 16–20 years and employees above 20 years experience. Therefore concerning leadership style perception, majority 40% of the males and 45% of the female prefer transformational leadership were as 35% of the males and 30% of the female have a preference of transactional leadership. Another type of leadership which is also viewed equally by 25% of employees comprises laissez faire. High communication inclusivity is reported by 40% males and 45% females, while 30% of each gender indicates moderate level. About 25% of the female participants stated their organizations are low in communication inclusion, while 30% of the male participants agreed. As for reward system fairness 50% of males and 55% of females find it fair and 50% of males and 45% of females find it unfair. While the level of stress at the first level is lower for males (15%) and females (10), stress at the second and third levels is higher for females (25% and 30) than males (20% and 25%). For the high stress levels (level 4 and 5), 25% males are stressed, 15% are stressed from level 5, 20% females are stressed from level 4, 15% from level 5. This satisfaction scale of the support system presents 45% of males and 50% of females as satisfied, 30% of males and 25% of females as indifferent, and 25% of both sexes dissatisfied. Males are only slightly disapproving of promotional satisfaction, with 40% satisfied, 30% neutral, and 30% dissatisfied; females have slightly more positive attitude with 45% satisfied, 30% neutral, and 25% dissatisfied. Last, training accessibility is pointed out by the 75% of the male respondents and 80% of the female's side, while only the 25% of the male respondents and the 20% of the female does not have the access to the trainings.

As shown in the above table 1.2 the correlation analysis provides a way of examining employee perceptions and experiences with various workplace variables and their interrelations. There is some evidence that different factors, important for the organization, correlate to a considerable extent. Experience proved to have a strong positive relation with Age Group ($r=0.939$) which of course is expected because with increase in years comes increase in experience. Also, Age Group possessed a strong positive relationship with Leadership Style Perception ($r = 0.892$) and Communication Inclusivity ($r = 0.875$), consequently, it was suggested that the senior employees have a more positive perception of leaders and communication strategies. Likewise, Age Group has a moderate association with Stress Level with a coefficient of 0.722, and strong connections with Support System Satisfaction and Promotion Satisfaction along with coefficients 0.812 and 0.778 respectively proving that Age Group affects workplace satisfaction. For experience, the relationships show positives across the different dimensions with relatively high coefficients. It is strongly correlate with Stress level (0.922), meaning that increase in experience level means the employee has to endure more stress at work. Further, Experience has positive and strong relationship with Reward System Fairness ($r = 0.853$) and Support System Satisfaction ($r = 0.854$) confirming the experience influence on perception of organizational fairness and support. This result has a high correlation with Promotion Satisfaction ($r = 0.834$) and Training Access ($r = 0.805$) to support experience as a factor affecting career mobility and training opportunities. Communication Inclusivity has a correlation coefficient of ($r = 0.982$) with the Perception of Leadership



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Style which defines the correlation between leadership practices and inclusion of others in communication. It also shows very high, almost perfect positive association with Reward System Fairness at ($r = 0.910$), Support System Satisfaction at ($r = 0.872$), and Promotion Satisfaction at ($r = 0.861$); it emphasizes that leadership can further the causes of fairness, support, and promotion satisfaction. In particular, Communication Inclusivity demonstrates significant positive relationships with Reward System Fairness (0.920), Support System Satisfaction ($r = 0.887$), and Promotion Satisfaction ($r = 0.869$). At the same time, the Experience Stress Level correlation reveals a close relation ($r = 0.922$), as does Training Access ($r = 0.782$) to Stress Level, where possible solutions might be required to decrease stress levels. Last, yet still a very significant correlation pattern is obtained with Support System Satisfaction featuring Promotion Satisfaction at ($r = 0.908$) showing how much a support system means to get promotion. As with Training Access, Leadership Style Perception also has a very positive correlation with Promotion Satisfaction ($r = 0.665$) and Training Access ($r = 0.875$) suggesting the role of training in raising employee standards and promotion satisfaction. This result highlights the cohesiveness of organizational factors and identifies potential areas for development including, communication, stress and support structures for increasing overall employee engagement.

RECOMMENDATIONS

- Encourage of Leadership Diversity training The Organizations should pursue leadership skills training that embraces leadership policies that are converged and support equal representation of women in organizations.
- Improve Communication Privilege the status of the women in the Organizations should be improved on communication and the Organizations should encourage women to participate more in communication.
- Rewards also needs to be reconsidered so that they do not actually promote masculinity and do not create racists bonuses.
- In honor of women, promotion and appreciation should be given to both output and teamwork since they are hidden in the work done by women.
- End/promote gender bias in promotion practices the Organizations should set standard procedure for promotion practice and the gender comparison should be conducted from time to time.
- There is a need for candidates for promotions to be offered in a nonselective manner so that both genders are given equal chance on the ladder.
- Gender Mainstreaming in the Workplace main action on which focus should be made on while constructing a gender-mainstreamed workplace.

CONCLUSION

The study confirms that organizational culture plays a critical role in perpetuating gender inequality in promotions. Leadership styles, communication practices, and reward systems all contribute to the barriers women face in career advancement. To ensure equal opportunities, organizations must actively address these biases by implementing inclusive policies, transparent communication practices, and equitable reward systems. By fostering a culture of inclusivity and fairness, organizations can help create a level playing field where both men and women have equal opportunities to succeed and advance in their careers.

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Table 1. Demographic Variables of the Respondents

	Demographic Variables	Male (n=100)	Female (n=100)
Age	25-30	20	20
	31-35	30	30
	36-40	20	20
	41-45	15	15
	Above 46	15	15
Experience (Years)	0-5	25	25
	6-10	35	35
	11-15	20	20
	16-20	10	10
	Above 20	10	10
Leadership Style Perception	Transformational	40	45
	Transactional	35	30
	Laissez-faire	25	25
Communication Inclusivity	High	40	45
	Medium	30	30
	Low	30	25
Reward System Fairness	Fair	50	55
	Unfair	50	45
Stress Level (1-5)	Low	15	10
	Mid Low	20	25
	Neutral	25	30
	High	25	20
	Very High	15	15





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Support System Satisfaction	Satisfied	45	50
	Neutral	30	25
	Dissatisfied	25	25
Promotion Satisfaction	Satisfied	40	45
	Neutral	30	30
	Dissatisfied	30	25
Training Access	Yes	75	80
	No	25	20

Table .2 Correlation Matrix of Employee Perceptions Workplace Variables

Variable	Age Group	Experience	Leadership Style Perception	Communication Inclusivity	Reward System Fairness	Stress Level	Support System Satisfaction	Promotion Satisfaction	Training Access
Age Group	1.000	0.939	0.892	0.875	0.845	0.722	0.812	0.778	0.801
Experience	0.939	1.000	0.925	0.902	0.853	0.922	0.854	0.834	0.805
Leadership Style Perception	0.892	0.925	1.000	0.982	0.910	0.842	0.872	0.861	0.875
Communication Inclusivity	0.875	0.902	0.982	1.000	0.920	0.857	0.887	0.869	0.850
Reward System Fairness	0.845	0.853	0.910	0.920	1.000	0.815	0.870	0.895	0.868
Stress Level	0.722	0.922	0.842	0.857	0.815	1.000	0.820	0.790	0.782
Support System Satisfaction	0.812	0.854	0.842	0.887	0.870	0.820	1.000	0.908	0.804
Promotion Satisfaction	0.778	0.834	0.861	0.869	0.895	0.790	0.908	1.000	0.872
Training Access	0.801	0.805	0.875	0.850	0.868	0.782	0.804	0.872	1.000





RESEARCH ARTICLE

Study of Incongruent Upshot of Nanosphere Technology and its Relevance

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ABSTRACT

A nanosphere is the division of polymeric nanoparticles having size range 10-200nm. The tiny capsule of drug store house is called vesicles and the solid skeleton structure is called Nanospheres. Nanospheres are biodegradable or non-degradable. It can enclose variety of drugs enzymes, genes and is characterized by a long circulation time. The review begins by presenting an overview of the diverse methods employed for nanospheres preparation, ranging from emulsion polymerization to template-assisted techniques. Each method is critically examined in terms of its principles, advantages, and limitations, offering readers insights into the nuanced selection of techniques based on specific application requirements. The physical and chemical properties of nanospheres, including size, morphology, surface charge, and composition, are discussed in detail. The relationship between these properties and the unique behaviors exhibited by nanospheres is explored, providing a foundation for understanding their applications. The subsequent sections delve into the manifold applications of nanospheres, emphasizing their pivotal role in drug delivery, imaging, catalysis, electronics, and environmental remediation. Specific examples highlight how nanospheres contribute to advancements in these fields, showcasing their potential for addressing complex challenges. Challenges and considerations associated with nanospheres, such as toxicity concerns, manufacturing scalability, and regulatory compliance, are also addressed. The review provides a brief explanation of formulation-related topics, such as the polymers utilized in its synthesis and the various methods for creating nanospheres. concerning the nanospheres' characterization parameters as well.

Keywords: Nanospheres, Polymerization, Biocompatibility, Coacervation, Bioavailability





INTRODUCTION

Drug discovery has advanced quickly as a result of nanotechnology's accelerated expansion; this is known as nano drug delivery system. It is the study of individual atoms in molecule or compounds to create materials with unique features. It is a study of tiny structures with lengths ranging from 1 to one 100 nanometers. Structure of Nanosphere is shown in Figure 1. Because nano drug delivery system can keep a medication in the blood stream for extended period of time, there will be a less variations in plasma levels and fewer adverse effects. These nano drug delivery systems contain a wide variety of nano carriers including carbon nanotubes, nanoparticles micelles, nanogels, nanospheres and nanocapsules.[1,8] The main objective of formulation of nanospheres is to controlling particle size dosing regimen and therapeutically releasing active ingredients are the primary goals of nanospheres formulation in order to achieve site-specific action at a therapeutically active pace. Nanosphere are polymeric matrix of spherical shape that ranges between 10 to 200 nm in diameter. the drug is dissolved, entrapped, encapsulated or attached to the matrix of polymer. The nature of the nanospheres can be amorphous or crystalline and they potentiate to protect the drug from chemical and enzymatic degradation.[2] Nanospheres are nano-sized particles that exhibit unique properties and find applications across a broad range of scientific, medical, and technological fields. Their small size, typically ranging from 1 to 100 nanometers in diameter, sets them apart from bulk materials and gives rise to distinctive physical, chemical, and biological behaviors.

KEY CHARACTERISTICS OF NANOSPHERES

1. **Size and Surface Area:** Nanospheres have an extraordinarily high surface area-to-volume ratio due to their diminutive size. This property contributes to their increased reactivity, making them ideal for various applications such as catalysis and drug delivery.
2. **Drug Delivery Vehicles:** In the field of medicine, nanospheres are extensively used as drug delivery vehicles. Their small size enables efficient transport across biological barriers, and they can be designed to encapsulate and deliver therapeutic agents with improved precision and controlled release.[3,9]
3. **Imaging Agents:** Nanospheres can be engineered to incorporate imaging agents for enhanced contrast in medical imaging techniques. This makes them valuable tools in diagnostics, allowing for better visualization of tissues and organs.
4. **Catalysis:** Due to their high surface area and unique chemical properties, nanospheres serve as efficient catalysts in chemical reactions. They find applications in catalysis to improve reaction efficiency and selectivity.[4]
5. **Versatility in Applications:** Nanospheres are employed in diverse fields, including electronics, optics, textiles, environmental remediation, and energy storage. Their versatility arises from the ability to customize their properties for specific functions.

METHODS OF PREPARATION

Several methods are employed for the preparation of nanospheres, each with its own advantages and limitations. The choice of method depends on the specific characteristics desired for the nanospheres, the intended application, and the type of materials used. Here are some common methods of nanosphere preparation and also shown in figure 3:

Emulsion Polymerization

Principle: Monomers are emulsified in a continuous phase, and polymerization occurs to form nanospheres.

Application: Used for the synthesis of polymer nanospheres, particularly in drug delivery systems.[5]

Solvent Evaporation

Principle: A polymer is dissolved in a volatile organic solvent, and nanospheres are formed when the solvent evaporates. **Application:** Widely used for drug delivery systems, allowing the encapsulation of drugs within the polymer matrix.[6]





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Spray Drying

Principle: Atomized polymer solution is sprayed into a drying chamber, resulting in the formation of dried nanospheres.

Application: Used for producing nanospheres with controlled release properties and improved stability.[9]

Coacervation

Principle: A polymer solution is destabilized, leading to the formation of a polymer-rich phase and subsequent nanosphere precipitation. **Application:** Suitable for the encapsulation of bioactive compounds in pharmaceuticals and food industries. [7]

Polymerization in Reverse Micelles

Principle: Monomers are encapsulated in reverse micelles, and polymerization occurs within these confined spaces to form nanospheres. **Application:** Used for the synthesis of polymer nanospheres with controlled size and properties.

Layer-by-Layer Assembly

Principle: Nanospheres are constructed by the sequential adsorption of oppositely charged polyelectrolytes onto a core material. **Application:** Suitable for the fabrication of multifunctional nanospheres for drug delivery and imaging.

Template-Assisted Methods

Principle: Nanospheres are synthesized using a sacrificial template that is later removed, leaving behind the nanospheres. **Application:** Template methods are versatile and used for a range of materials, including metals, polymers, and ceramics.[8]

Nano-precipitation

Principle: A polymer is dissolved in a water-miscible organic solvent, which is then rapidly injected into an aqueous solution to induce nanosphere formation. **Application:** Commonly used for the preparation of nanospheres in drug delivery systems.

Self-Assembly

Principle: Nanospheres are formed through the self-organization of amphiphilic molecules or block copolymers.

Application: Used for the fabrication of nanospheres with specific structural and functional properties.[9]

Electro-spraying

Principle: A polymer solution is electrically charged and sprayed to form nanospheres. **Application:** Used for the preparation of nanospheres with a narrow size distribution and high encapsulation efficiency.

Micro fluidic Techniques

Principle: Controlled mixing of fluids at the micro scale leads to the formation of nanospheres. **Application:** Enables precise control over the size and properties of nanospheres.[10]

POLYMERIZATION METHOD

This Method is also known as **Interfacial** polymerization and **Emulsification** polymerization. In this method polymers are emulsified i.e. Emulsification polymerization. Procedure given in figure 4. Monomers are polymerized to form nanosphere (In aqueous solution) (After completion of polymerization)The drug is incorporated by dissolving in the polymerization medium.(Via adsorption onto nanosphere) Nanospheres are obtained. (Then purified, centrifuged and finally freeze dried)[11]



**DESOLVATION TECHNIQUE**

The polymeric solution was prepared. (By using poly ethylene glycol) After drug dissolved in organic solvent (Ethanol) The above solution (organic phase) was added drop wise into polymeric solution. (Under Magnetic Stirring) After then cross linking agent is added (Continue the process for 12 hrs) finally nanosphere suspension was obtained (centrifuged and lyophilized). Procedure given in figure 5.

SOLVENT EVAPORATION METHOD

The polymer dissolved in suitable organic solvent (Mixture sonicated for 2mins) Then drug is dispersed into the previous solution (And again sonicated for 2 min) This above mixture is then emulsified using suitable emulsifying agent to form o/w emulsion. Emulsion is subjected to solvent evaporation via continuous mixing or Increasing temperature or by Reducing pressure. Nanosphere is formed.[12]. Procedure given in figure 6

SALTING OUT METHOD

The polymer dissolved in suitable organic solvent. Then organic phase dissolved in aqueous phase. (That contains suitable emulsifier and high concentration of salts) Under mechanical shear to induce emulsification and formed o/w emulsion. Then pure water added to above emulsion.(Under mild stirring to enhance diffusion of organic solvent into the aqueous phase phase to form nanosphere) Finally nanospheres purified. (By centrifugation and remove salting out agent)[13] Procedure given in figure 7

IONIC GELATION

This method is also called as Coacervation method.

In this method nanosphere are prepared by using natural polymers like chitosan, gelatin, and sodium alginate. Aqueous solution of polymer and drug is taken. Cross linking agent added to another aqueous phase. Due to electrostatic interaction of two phases They form particle size in nanometer range.[14] Procedure given in figure 8

SPRAY DRYING

It is a widely used technique for the formulation of nanospheres, especially in the pharmaceutical and food industries. Procedure given in figure 9

Begin with a liquid nanosphere formulation, typically a solution or suspension of nanoparticles in a suitable solvent. This formulation may contain polymers, drugs, or other materials depending on the intended application.[15]

Atomization

The liquid nanosphere formulation is pumped through a nozzle or atomizer to break it into small droplets. Atomization is a crucial step as it influences the size and morphology of the resulting nanospheres.[16] **Drying** The

atomized droplets are introduced into a drying chamber. The drying chamber is usually a hot environment, often maintained at temperatures above the boiling point of the solvent used in the formulation. **Evaporation of Solvent**

As the nanosphere droplets travel through the drying chamber, the solvent evaporates, leaving behind solid nanospheres. The drying process is rapid, helping to maintain the original nanosphere size and morphology.[15]

Collection The dried nanospheres are collected from the outlet of the drying chamber. The collection system may include a cyclone or other equipment to separate the nanospheres from the drying air.

CHARACTERIZATION OF NANOSPHERES

The characterization of nanospheres involves analyzing and understanding their physical, chemical, and structural properties. This process is crucial for ensuring the desired performance in various applications. [17] Here are some common techniques used for the characterization of nanospheres:

Size and Morphology

- **Scanning Electron Microscopy (SEM):** SEM provides high-resolution images of the surface morphology of nanospheres, allowing for the determination of size, shape, and uniformity.[18]





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- **Transmission Electron Microscopy (TEM):** TEM provides detailed images of the internal structure of nanospheres, revealing information about their size, shape, and internal features.

Chemical Composition

- **Energy-Dispersive X-ray Spectroscopy (EDS):** EDS, coupled with SEM or TEM, allows for the elemental analysis of nanospheres, providing information about their chemical composition.[19]
- **X-ray Photoelectron Spectroscopy (XPS):** XPS is used to analyze the surface chemistry of nanospheres, providing information about the elemental composition and chemical states of the elements.[20]

Crystal Structure

- **X-ray Diffraction (XRD):** XRD is employed to determine the crystal structure of nanospheres, providing information about their crystallinity, crystal size, and phase composition.[21]

Surface Area and Porosity

- **BET (Brunauer-Emmett-Teller) Analysis:** BET analysis is used to measure the specific surface area and porosity of nanospheres, providing insights into their surface characteristics and adsorption properties.

Zeta Potential and Surface Charge

- **Zeta Potential Analysis:** Zeta potential measurements provide information about the surface charge of nanospheres, influencing their stability, dispersion, and interactions in solution.[22]

Thermal Properties

Differential Scanning Calorimetry (DSC): DSC measures the heat flow associated with phase transitions and chemical reactions, providing information about the thermal properties of nanospheres.[23]

Magnetic Properties

Magnetic Property Measurements: For nanospheres with magnetic properties, techniques such as vibrating sample magnetometer (VSM) can be employed to characterize their magnetic behavior.[24]

Optical Properties

UV-Visible Spectroscopy: UV-Visible spectroscopy is used to study the absorption and scattering properties of nanospheres, providing information about their optical characteristics.[25]

Rheological Properties

Rheological Analysis: Rheological studies can be conducted to understand the flow and deformation behavior of nanosphere-containing materials, which is important in applications such as coatings and composites.[26]

Release Kinetics (for Drug Delivery):

In vitro Release Studies: In drug delivery applications, the release kinetics of drugs from nanospheres can be characterized using various techniques to understand the controlled release behavior

POLYMERS USED IN THE DESIGN OF NANOSPHERE

Various polymers are used in the design and synthesis of nanospheres, each offering unique properties that suit specific applications. The choice of polymer depends on factors such as biocompatibility, biodegradability, mechanical properties, and the intended function of the nanosphere.[27] Here are some commonly used polymers in the design of nanospheres and also listed in figure 2:

1. **Poly (lactic-co-glycolic acid) (PLGA):** Biodegradable, biocompatible, and widely used in drug delivery. **Applications:** Drug encapsulation and controlled release.





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2. **Polyethylene glycol (PEG):** Hydrophilic, non-toxic, and resistant to protein adsorption. **Applications:** Surface modification to enhance biocompatibility and reduce immunogenicity.
3. **Polyvinyl alcohol (PVA):** Water-soluble, biocompatible, and film-forming. **Applications:** Drug delivery, particularly in combination with other polymers.
4. **Chitosan:** Derived from chitin, biodegradable, and biocompatible. **Applications:** Drug delivery, wound healing, and tissue engineering.
5. **Poly (ethyleneimine) (PEI):** Cationic polymer with high transfection efficiency. **Applications:** Gene delivery and DNA encapsulation.
6. **Poly (alkyl cyanoacrylate):** Biodegradable and biocompatible. **Applications:** Drug delivery, particularly for crossing the blood-brain barrier.
7. **Poly (L-lysine)** positively charged and biodegradable. **Applications:** Gene delivery and drug delivery.
8. **Polystyrene:** Stable, rigid, and hydrophobic. **Applications:** Microspheres for drug delivery, diagnostics, and as model systems in research.
9. **Poly (caprolactone) (PCL):** Biodegradable and exhibits slow degradation. **Applications:** Drug delivery, tissue engineering, and controlled release.
10. **Polyamidoamine (PAMAM):** Dendrimeric structure, with well-defined size and surface groups. **Applications:** Drug delivery, imaging, and gene delivery.
11. **Hydro gels (various polymers):** Highly hydrated, biocompatible, and suitable for controlled drug release. **Applications:** Drug delivery, wound healing, and tissue engineering.
12. **Poly (N-isopropylacrylamide) (PNIPAAm):** Thermo responsive, undergoing a phase transition around body temperature. **Applications:** Drug delivery and temperature-sensitive nanospheres. The selection of a specific polymer depends on the desired characteristics for a particular application, such as sustained drug release, targeted delivery, or imaging capabilities. Additionally, many nanospheres are designed using a combination of polymers to achieve a synergistic effect and enhance overall performance.[28]

ADVANTAGES OF NANOSPHERES

Nanospheres offer numerous advantages across various fields due to their unique properties. Here are some key advantages of nanospheres:

1. **High Surface Area:** Nanospheres have an exceptionally high surface area-to-volume ratio due to their small size. This property enhances their reactivity and makes them ideal for applications requiring surface interactions, such as catalysis and drug delivery.[29]
2. **Drug Delivery:** Nanospheres are widely used in drug delivery systems. Their small size allows for efficient transport across biological barriers, and they can be designed to encapsulate and deliver drugs with improved bioavailability, targeted delivery, and controlled release.
3. **Targeted Delivery:** The small size of nanospheres enables targeted delivery of therapeutic agents to specific cells or tissues. This reduces systemic side effects and enhances the effectiveness of treatments, particularly in cancer therapy.[30]
4. **Improved Stability:** Nanospheres can improve the stability of sensitive compounds, such as drugs or imaging agents. They can protect these materials from degradation, ensuring their efficacy over time.
5. **Enhanced Imaging:** In biomedical applications, nanospheres can be engineered with imaging agents to enhance contrast in various imaging modalities. This facilitates better visualization of tissues and organs in medical diagnostics.
6. **Versatility in Material Composition:** Nanospheres can be synthesized from a wide range of materials, including polymers, metals, and ceramics. This versatility allows for tailoring their properties to meet specific requirements in different applications.
7. **Controlled Release:** Nanospheres can be designed to release encapsulated substances in a controlled manner. This is particularly advantageous in drug delivery, where sustained and controlled release can improve therapeutic outcomes.
8. **Improved Bioavailability:** The small size of nanospheres can improve the bioavailability of poorly soluble drugs by enhancing their solubility and dissolution rate, leading to more effective drug delivery.[31]





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9. **Biocompatibility:** Many nanosphere materials exhibit good biocompatibility, making them suitable for various biomedical applications. This is crucial for minimizing adverse effects when used in medical treatments.
10. **Efficient Catalysis:** Nanospheres, particularly those made from specific materials, can serve as efficient catalysts in chemical reactions. Their high surface area and unique properties make them effective in catalyzing reactions with improved efficiency and selectivity.
11. **Customizable Properties:** The properties of nanospheres, such as size, shape, and surface charge, can be finely tuned during synthesis. This allows for the customization of nanospheres to meet specific requirements in different applications.[32]
12. **Environmental Applications:** Nanospheres can be employed in environmental remediation, such as pollutant removal and water purification, leveraging their unique properties to address environmental challenges.

DISADVANTAGES OF NANOSPHERES

While nanospheres offer various advantages, there are also potential disadvantages and challenges associated with their use. It's important to consider these factors when exploring applications of nanospheres. Some of the disadvantages include:

1. **Toxicity Concerns:** Certain nano materials may exhibit unexpected toxicity, especially when they interact with biological systems. Understanding the biocompatibility and potential long-term effects is crucial for applications involving nanospheres, particularly in medical and pharmaceutical fields.[33]
2. **Biological Interactions:** Nanospheres can interact with biological systems in ways that are not fully understood. This may lead to unpredictable responses, and thorough studies are necessary to assess their impact on cells, tissues, and organisms.
3. **Manufacturing Challenges:** The production of nanospheres can be complex and may involve intricate synthesis methods. Consistent and scalable manufacturing processes can be challenging to achieve, impacting the reproducibility and cost-effectiveness of nanosphere production.[4]
4. **Agglomeration and Stability Issues:** Nanospheres may have a tendency to agglomerate, affecting their stability and performance. Agglomeration can reduce the specific surface area and alter the properties of the nanospheres, impacting their intended functions.
5. **Limited Understanding of Long-Term Effects:** The long-term effects of exposure to nanospheres, especially in medical and environmental applications, are not fully understood. Continuous research is needed to assess the safety and potential risks associated with prolonged exposure.
6. **Regulatory Challenges:** The regulatory landscape for nanomaterials is still evolving, and there may be challenges in establishing standardized testing and safety protocols. Compliance with regulatory requirements can pose hurdles in the development and commercialization of nanosphere-based products.
7. **Environmental Impact:** The disposal of nanomaterials, including nanospheres, raises concerns about their potential environmental impact. The long-term effects of these materials on ecosystems and wildlife need to be carefully considered.
8. **Cost Considerations:** The production of nanospheres, especially those made from specialized materials, can be expensive. High production costs may limit the widespread adoption of nanospheres in certain applications.
9. **Limited Understanding of Fate and Transport:** Understanding the fate and transport of nanospheres in biological systems and the environment is crucial. The lack of comprehensive knowledge in this area can impede the safe and responsible use of nanospheres.
10. **Ethical Considerations:** Ethical concerns related to the use of nanospheres, especially in medical applications, may arise. Issues such as informed consent, privacy, and the potential for misuse should be carefully addressed.

CHALLENGES ASSOCIATED WITH NANOSPHERE FORMULATION:

The formulation of nanospheres involves addressing several challenges to ensure their stability, functionality, and safety. Here are some common challenges associated with nanosphere formulation:

1. **Size Control:** Achieving precise control over the size of nanospheres is crucial for their intended applications. Variability in size can affect drug release kinetics, cellular uptake, and overall performance. Consistent and reproducible size control remains a challenge in nanosphere formulation.





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2. **Polydispersity:** Polydispersity refers to the distribution of sizes within a batch of nanospheres. High polydispersity can lead to uneven drug release and may impact the overall efficacy of the nanosphere formulation. Minimizing polydispersity is a key challenge in achieving uniform and predictable performance.[35]
3. **Stability Issues:** Nanospheres may experience stability issues such as aggregation, sedimentation, or precipitation over time. Maintaining the stability of nanospheres during storage and transportation is a significant challenge, especially when dealing with nanoparticles prone to agglomeration.
4. **Drug Loading and Release Kinetics:** Efficient loading of therapeutic agents into nanospheres and controlling their release kinetics pose challenges. Achieving a high drug-loading capacity without compromising the stability and integrity of the nanospheres can be technically demanding.
5. **Biocompatibility and Toxicity:** Ensuring the biocompatibility of nanosphere formulations is critical for medical applications. Understanding and mitigating potential toxic effects, especially for long-term use, is a challenge that requires comprehensive toxicity studies.
6. **Manufacturing Scalability:** Transitioning from lab-scale synthesis to large-scale production while maintaining the desired characteristics of nanospheres can be challenging. Achieving reproducibility, consistency, and cost-effectiveness in large-scale manufacturing is a hurdle in the commercialization of nanosphere formulations.[36]
7. **Surface Modification and Functionalization:** Surface modification is often required to impart specific properties to nanospheres, such as improved biocompatibility or targeting capabilities. Achieving effective surface modification without altering the overall characteristics of the nanospheres presents a formulation challenge.
8. **Regulatory Compliance:** The regulatory landscape for nano materials, including nanospheres, is evolving. Meeting regulatory requirements and establishing standardized testing protocols for safety and efficacy can be challenging but is essential for approval and market acceptance.
9. **Understanding In Vivo Behavior:** Studying the in vivo behavior of nanospheres, including their pharmacokinetics, biodistribution, and clearance mechanisms, is complex. The challenge lies in developing reliable models and methodologies to accurately assess the performance of nanosphere formulations within living organisms.[6]
10. **Cost Considerations:** The cost of raw materials, synthesis processes, and characterization techniques for nanospheres can be high. Achieving cost-effective formulations that meet quality standards and regulatory requirements is a challenge for widespread adoption in various applications.

APPLICATIONS

Nanospheres, which are nano-sized spherical particles, find applications across various fields due to their unique properties. Here are some applications of nanospheres:

1. **Drug Delivery:** Nanospheres can be used in drug delivery systems to encapsulate and deliver pharmaceutical agents. Their small size allows for targeted delivery, improving drug efficacy while minimizing side effects.[4]
2. **Biomedical Imaging:** Nanospheres can be designed with imaging agents for applications in medical imaging. These particles enhance contrast in imaging techniques like magnetic resonance imaging (MRI) or fluorescence imaging.
3. **Cancer Treatment:** In cancer therapy, nanospheres can be engineered to deliver anticancer drugs specifically to tumor cells, minimizing damage to healthy cells. Additionally, they can be used for imaging tumors and monitoring treatment response.
4. **Cosmetics:** Nanospheres are used in cosmetics for controlled release of active ingredients, improving the stability and effectiveness of skincare products. They can enhance the delivery of vitamins, antioxidants, and other beneficial compounds.[16]
5. **Food and Beverage Industry:** Nanospheres can be employed for encapsulating flavors, nutrients, or additives in food and beverages. This allows for controlled release and improved stability of sensitive compounds.[12]
6. **Environmental Remediation:** Nanospheres can be utilized in environmental applications, such as water purification and pollutant removal. They can absorb or catalyze pollutants, aiding in the remediation of contaminated environments.





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7. **Electronics and Optics:** In electronics, nanospheres can be used for coating surfaces to provide enhanced conductivity, improved insulation, or as components in advanced electronic devices. In optics, they can be employed for light manipulation and as components in nanophotonic devices.
8. **Catalysis:** Nanospheres can serve as catalysts in various chemical reactions due to their high surface area and unique chemical properties. They find applications in improving reaction efficiency and selectivity.[31]
9. **Textiles:** Nanospheres can be incorporated into fabrics for applications such as stain resistance, water repellency, or antimicrobial properties. These enhancements improve the durability and functionality of textiles.
10. **Energy Storage:** In the field of energy storage, nanospheres can be used in the development of advanced batteries and super capacitors. Their unique properties can contribute to improved energy density and storage capabilities.

RECENT ADVANCES IN NANOSPHERE FORMULATIONS

1. **Multifunctional Nanospheres:** Recent research focuses on designing nanospheres with multiple functionalities, such as combining drug delivery with imaging capabilities. These multifunctional nanospheres aim to enhance diagnostic and therapeutic approaches, providing more comprehensive solutions in medicine.[14]
2. **Targeted Drug Delivery Systems:** Advances in nanosphere research are directed towards improving targeted drug delivery. Strategies include the use of ligands on nanospheres' surfaces for specific targeting of diseased cells or tissues, reducing side effects and improving therapeutic efficacy.
3. **Responsive Nanospheres:** Scientists are developing nanospheres that respond to specific environmental cues. These responsive nanospheres can release drugs or change their properties in response to changes in pH, temperature, or other physiological conditions, providing a more controlled and tailored approach.
4. **In Vivo Imaging Nanospheres:** Recent advances include the development of nanospheres for in vivo imaging with improved sensitivity and resolution. These nanospheres can be used for early detection of diseases and monitoring treatment responses.[17]
5. **Biodegradable Nanospheres:** Sustainable and biodegradable nanospheres are gaining attention to address environmental concerns. These nanospheres can be designed to degrade after fulfilling their intended purpose, reducing long-term environmental impact.
6. **Nano structured Materials:** Advances in nanosphere synthesis involve the exploration of various nano structured materials, including hybrid nanospheres and nano composites. These materials offer unique properties and functionalities for applications in diverse fields.
7. **Nanosphere-Based Vaccines:** Researchers are investigating nanosphere-based vaccine delivery systems, aiming to enhance vaccine efficacy and improve immune responses. Nanospheres can serve as efficient carriers for antigens, adjuvants, and other vaccine components.[5]
8. **3D Printing of Nanospheres:** Innovations in nanosphere manufacturing include the integration of 3D printing technologies. This approach allows for precise control over nanosphere structures and properties, enabling customized applications in medicine, electronics, and materials science.
9. **Nanosphere-Based Sensors:** Nanosphere-based sensors are being explored for their applications in detecting various analyte, including biomarkers and environmental pollutants. These sensors leverage the unique properties of nanospheres to achieve high sensitivity and selectivity.[6]
10. **Nanospheres for Energy Storage:** Recent research is focusing on using nanospheres in energy storage devices, such as batteries and super capacitors. The high surface area and unique properties of nanospheres can enhance the performance and efficiency of these energy storage systems.

CONCLUSION

This comprehensive review has illuminated the multifaceted world of nanospheres, underscoring their significance in diverse scientific, medical, and technological realms. The synthesis methods discussed showcase the versatility available to researchers and engineers, allowing them to tailor nanospheres for specific applications with precision



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and control. The exploration of physical and chemical properties has unveiled the unique behaviors inherent in nanospheres, laying the groundwork for harnessing these characteristics in innovative ways. The myriad applications of nanospheres, ranging from drug delivery and imaging to catalysis and environmental remediation, highlight their transformative potential across various disciplines. The examples presented underscore the pivotal role nanospheres play in advancing technological frontiers, offering solutions to intricate challenges and propelling progress in fields critical to human well-being. However, the review also delves into the challenges and considerations surrounding nanospheres, emphasizing the importance of addressing issues such as toxicity, scalability, and regulatory compliance. Recognizing and navigating these challenges are crucial for the responsible development and widespread adoption of nanosphere-based technologies. Looking ahead, the dynamic nature of nanosphere research promises continued breakthroughs and innovations. As scientists delve deeper into understanding nanosphere behavior and refine synthesis techniques, new frontiers are likely to emerge. [14] The potential for collaborative efforts across disciplines, from chemistry to medicine and beyond, holds the key to unlocking the full spectrum of possibilities inherent in nanospheres. In the grand tapestry of nanotechnology, nanospheres stand as miniature marvels, offering a pathway to precision and efficiency in applications that impact our daily lives. This review serves as a comprehensive guide, shedding light on the current state of nanosphere research while pointing to future directions. As researchers continue to unravel the mysteries of nanospheres, their journey promises to be one of continuous discovery, innovation, and transformative impact.

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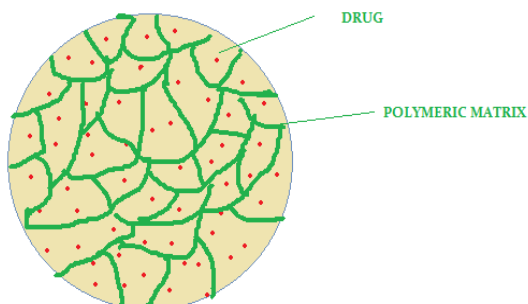


Figure 1: Nanosphere Structure

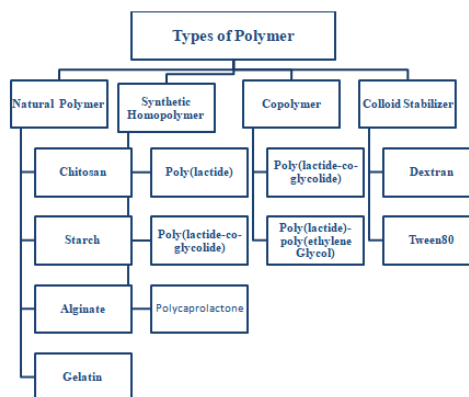


Figure 2: Polymers Used in the Design of Nanosphere

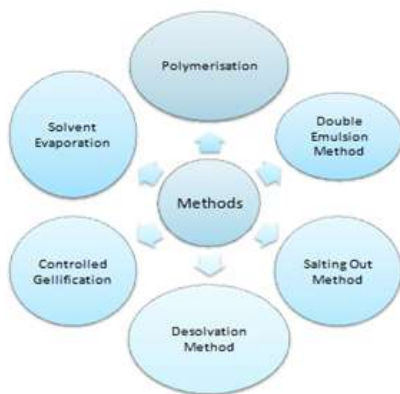


Figure 3: Various methods of preparation of nanospheres

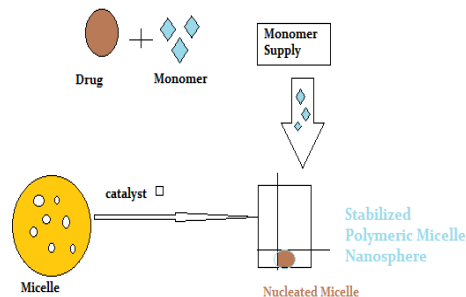


Figure 4: Polymerization Method

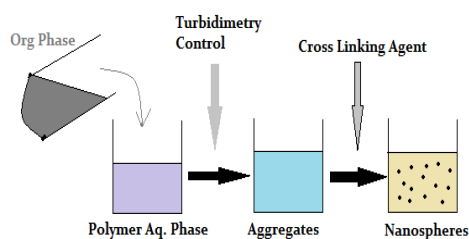


Figure 5: Desolvation Method

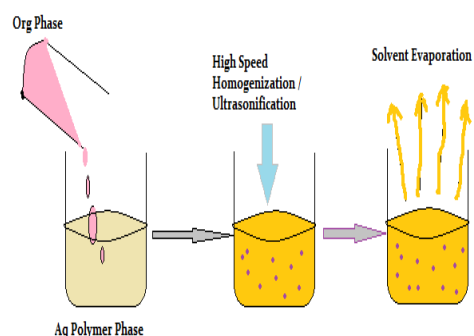
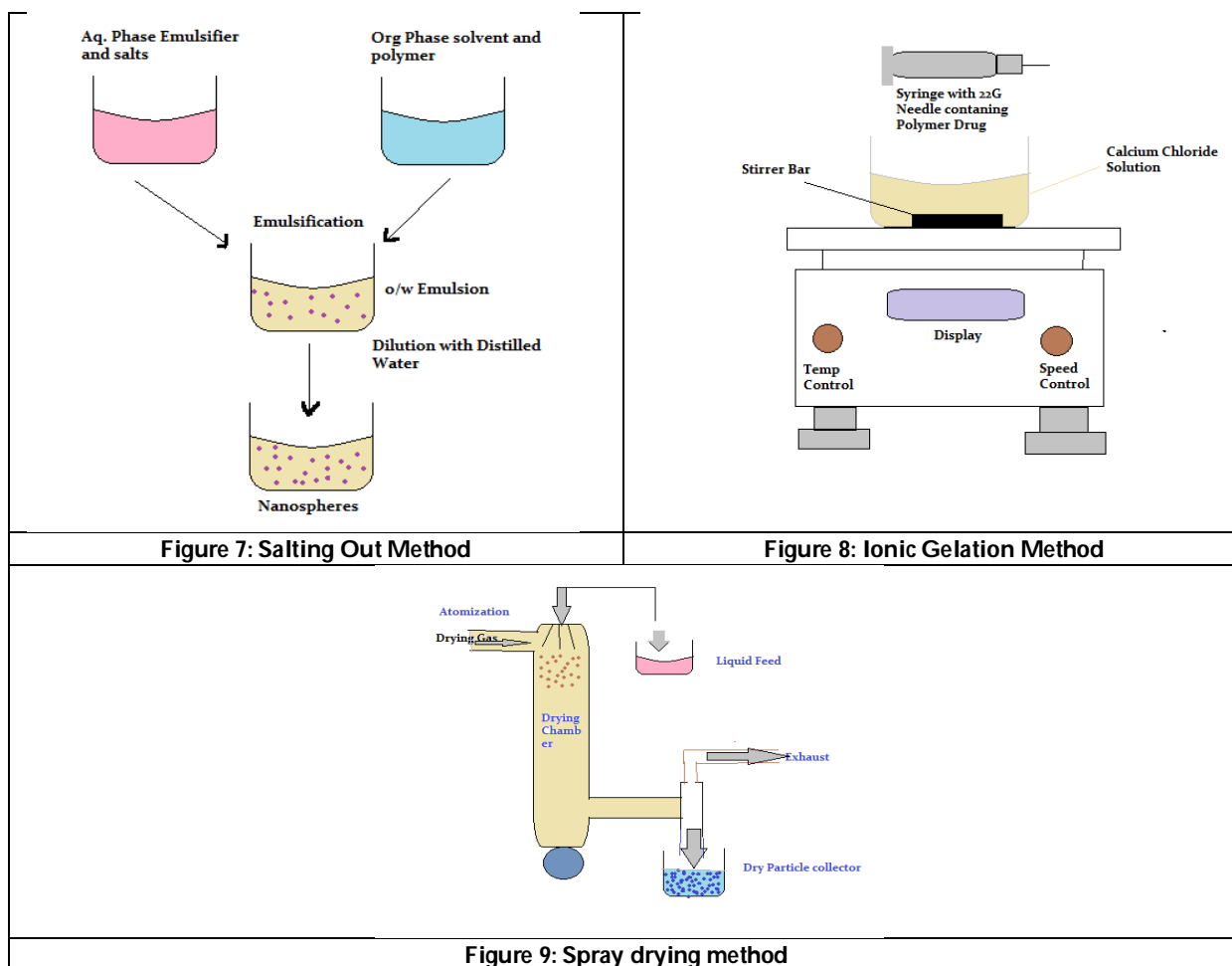


Figure 6: Solvent Evaporation Method





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Plithogenic Decision Making with Different Linguistic Contradiction Degrees Representations

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ABSTRACT

Plithogenic sets are more significant in determining optimal solutions to intricate decisioning problems. A plithogenic set is a quintuple of the form (P, a, V, d, c) which is characterized by attributes, attribute values, degrees of appurtenance and contradiction. This research work presents a decision-making model based on plithogenic method of contradictions considering different linguistic degrees of contradictions. The proposed model is validated with the decisioning on renewable energy systems. The decisioning model developed in this work consists of several alternative energy sources and the related criteria. The linguistic representations of the contradiction degrees are quantified using fuzzy, intuitionistic and neutrosophic sets. The rankings of the alternatives based on the method of contradictions obtained using different representations are compared to analyze the efficacy of different representations of linguistic variables. This study explores the competency of different quantifications of linguistic representations in facilitating the decision makers to derive optimal solutions to the problem of alternative renewable energy resources.

Keywords: Plithogenic sets, Linguistic variable, contradiction degree, renewable energy systems.





INTRODUCTION

Smarandache developed Plithogenic sets to generalize the existing sets of different kinds. The construction of this set as a quintuple (P, a, V, d, c) is more concerned on attributes and attribute values. The plithogenic sets are categorized into fuzzy, intuitionistic and neutrosophic based on the nature of the appurtenance degree (d) which represent the association between the elements of the set P and the attribute values belonging to the set V subjected to the attribute say 'a'. The contradiction degree exhibits the differences between the attribute values, however, the contradiction degree assumes a numerical value and this do not contribute to the classification of the plithogenic sets. In general, the contradiction degree needs to be represented using linguistic variable to facilitate the decision makers to express their opinion on the choice of the dominant attribute value and its differences between the other attribute values. Nivetha *et al*[14] employed linguistic representation of the contradiction degrees in developing a decisioning model using Plithogenic cognitive maps and it was quantified using fuzzy representations. This is the ground work of this proposed decisioning approach and this serves as a motivating key to extend and explore the linguistic variable quantification using different representations. The theory of Plithogeny is getting augmented at recent times and its implications is witnessed in several areas of decisioning especially in multi -criteria optimization. Sudha *et al*[21] presented a review of applications of plithogenic based multi-criteria decision methods. To mention a few, Ozcil *et al*[17] in performance appraisal, Ahmad *et al*[2] in ranking the alternatives, Abdel *et al*[1] in health care, Grida *et al*[10] in supply chain. Plithogenic based hypersoft sets are also applied in diverse decisioning, some of the noteworthy works contributed to literature are Dhumras *et al*[5] in medical diagnosis, Martin *et al*[13] in Covid diagnosis, Hema *et al*[11] in ranking of the alternatives. Plithogenic graphs are also discussed, some significant contributions are made by Fujita[9], Martin *et al*[12], Azeem *et al*[3]. The concept of Plithogeny is integrated with graphs and applied in decisioning. The aforementioned applications exhibit and demonstrate the efficacy of Plithogenic sets in multicriteria decisioning. This has motivated the authors to apply Plithogenic based decisioning in making optimal decisions on alternative energy resources. On other hand, in the above discussed literature, the contradiction degrees are represented numerically and only in a very few plithogenic representations, the contradiction degrees are represented using linguistic variables especially using fuzzy membership values. However, the other representations of linguistic variables using intuitionistic or neutrosophic membership values are not much leveraged and comparisons of the quantifications are also not much explored to the best of our knowledge. This fostered the authors to initiate the linguistic depictions of contradiction degrees using different representations and comparisons of the same. The remaining contents of the paper are enfolded in to the following sections. The preliminaries are presented in section 2. The methodology is outlined in section 3. The proposed decisioning approach is applied in section 4. The results are discussed in section 5 and the last section concludes the work.

PRELIMINARIES

This section presents the fundamentals essential for this research work.

Definition 2.1 Fuzzy set[15]

Let U be the universe of discourse, a fuzzy set A is attributed by a membership function μ_A of the form $\mu_A : U \rightarrow [0,1]$, where $\mu_A(u) \in [0,1]$ represents the membership value of u in A

Definition 2.2 Intuitionistic set[8]

Let U be the universe of discourse, an intuitionistic fuzzy set A is attributed by a membership function μ_A and non-membership function ν_A of the form $\mu_A(x), \nu_A(x) : X \rightarrow [0,1]$. The intuitionistic set assumes the form of $A = \{ \langle x, \mu_A(x), \nu_A(x) \rangle : x \in X \}$, where $0 \leq \mu_A + \nu_A \leq 1$

Definition 2.3 Neutrosophic set[19]

Let U be the universe of discourse, a neutrosophic set A is attributed by a truth function μ_A , indeterminacy function σ_A and falsity function γ_A of the form $\mu_A(x), \sigma_A(x), \gamma_A(x) : X \rightarrow [0,1]$. The neutrosophic set assumes the form of $A = \{ \langle x, \mu_A(x), \sigma_A(x), \gamma_A(x) \rangle : x \in X \}$, where $0 \leq \mu_A(x) + \sigma_A(x) + \gamma_A(x) \leq 3$



**Definition 2.4 Plithogenic Set[20]**

Plithogenic set is characterized as the generalization of crisp, fuzzy, intuitionistic, and neutrosophic set. Let U be the universal set, a plithogenic set is of the form (P, a, V, d, c) where the set is denoted by P , attribute by a , attribute values by V , degree of appurtenance by d and contradiction degree by c , where $d: P \times V \rightarrow \rho([0,1]^z)$, $c: V \times V \rightarrow [0,1]^z$

Definition 2.5 Triangular Fuzzy Number[6]

A triangular fuzzy number $\tilde{a} = (a^l, a^m, a^n)$ is a fuzzy set defined on the set R of real numbers, whose membership function is defined as follows:

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{(a^n - x)/(a^n - a^m)}{a^m - a^l}, & \text{if } a^m \leq x \leq a^n \\ \frac{x - a^l}{a^m - a^l}, & \text{if } a^l \leq x \leq a^m \\ 0, & \text{if } x > a^n \text{ or } x < a^l \end{cases}$$

Where a^l, a^m and a^n are called the lower bound, the mode and the upper bound of the triangular fuzzy number.

Definition 2.6 Triangular Intuitionistic Fuzzy number[7]

A triangular intuitionistic fuzzy number $\tilde{a} = ((\underline{a}, a, \bar{a}), \mu_{\tilde{a}}, \nu_{\tilde{a}})$ is a special IFS on a real number set R , its membership function is defined as follow:

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x - \underline{a}}{a - \underline{a}} \mu_{\tilde{a}}, & \text{if } \underline{a} < x \leq a \\ \mu_{\tilde{a}}, & \text{if } x = a \\ \frac{\bar{a} - x}{\bar{a} - a} \mu_{\tilde{a}}, & \text{if } a < x \leq \bar{a} \\ 0, & \text{if } x < \underline{a} \text{ or } x > \bar{a} \end{cases}$$

And its non-membership function can be defined as :

$$\nu_{\tilde{a}}(x) = \begin{cases} \frac{a - x + (x - \underline{a})}{a - \underline{a}} \nu_{\tilde{a}}, & \text{if } \underline{a} < x \leq a \\ \nu_{\tilde{a}}, & \text{if } x = a \\ \frac{x - a + (\bar{a} - x)}{\bar{a} - a} \nu_{\tilde{a}}, & \text{if } a < x \leq \bar{a} \\ 1, & \text{if } x < \underline{a} \text{ or } x > \bar{a} \end{cases}$$

Where $\mu_{\tilde{a}}$ and $\nu_{\tilde{a}}$ are the maximal membership degree and the minimal non-membership degree respectively, and they satisfy the condition $0 \leq \mu_{\tilde{a}} \leq 1$, $0 \leq \nu_{\tilde{a}} \leq 1$.

Definition 2.7 Triangular Neutrosophic fuzzy number[18]

Let $a_1 \leq b_1 \leq c_1$ such that $a_1, b_1, c_1 \in R$. A triangular neutrosophic number $\tilde{A} = \langle (a_1, b_1, c_1); w_A, u_A, y_A \rangle$ is a special neutrosophic set on the real number set R , whose truth-membership function $\mu_A: R \rightarrow [0, w_A]$, indeterminacy-membership function $\nu_A: R \rightarrow [u_A, 1]$ and falsity-membership function $\lambda_A: R \rightarrow [y_A, 1]$ respectively.

Definition 2.8 Defuzzification of Triangular Fuzzy Number

A triangular fuzzy number $A = (a, b, c)$ is defuzzified using

$$FT_F(A) = \frac{(a + b + c)}{3}$$

Definition 2.9 Score of Triangular Intuitionistic Fuzzy number[16]

If $B = ((a, b, c), w_a, u_a)$ is a triangular intuitionistic fuzzy number, then

$$IT_F(B) = \frac{1}{12} \left[\frac{4b - 2(a + c) + 3w_a(a + c)}{w_a} + \frac{2(a + b + c) - 3u_a(b + a)}{(1 - u_a)} \right]$$

Definition 2.10 Deneutrosophication of Triangular Neutrosophic fuzzy number[4]

If $C = ((a, b, c), (d, e, f), (g, h, k))$ is a triangular neutrosophic fuzzy number, then

$$NT_F(C) = \frac{(a + 2b + c + d + 2e + f + g + 2h + k)}{12}$$





METHODOLOGY

This section describes the steps to be followed in ranking the alternatives using linguistic variable representation of contradiction degrees.

Step 1 : Definition of the problem

In this step, the problem to be addressed is defined. The alternatives, criteria and the criterion values are tabulated together with the decision of the dominant criterion values. The criteria are classified into benefit and non-benefit. The decision-making matrix associating both the alternatives and the criteria with criterion values is formulated.

$$D_L = \begin{pmatrix} b_{L11} & \dots & b_{L1n} \\ \vdots & \ddots & \vdots \\ b_{Lm1} & \dots & b_{Lmn} \end{pmatrix}$$

Step 2: Computation of Criterion Weights

The criterion weights are calculated using the existing methods of multi-criteria decisioning. In general the criterion weights say w_1, w_2, \dots, w_m are assumed to be equal such that $\sum_{k=1}^m w_k = 1$

Step 3 : Formulation of linguistic contradiction matrix

The contradiction matrix containing the linguistic representation of the contradiction degree of the criterion values with regard to dominant criterion values is framed.

$$C_L = \begin{pmatrix} c_{LD11} & \dots & c_{LD1n} \\ \vdots & \ddots & \vdots \\ c_{LDm1} & \dots & c_{LDmn} \end{pmatrix}$$

Each of the values in the cells is either of the form presented in Definition

Step 4 : Quantification of linguistic contradiction degree

The contradiction degree represented using linguistic contradictions is quantified using either fuzzy numbers, intuitionistic numbers and neutrosophic numbers as mentioned in Definitions 2.8 -2.10.

Step 5 : Framing of weighted contradiction matrix

The contradiction matrix $[C_L]$ is multiplied with the criterion weights to frame the weighted contradiction matrix $[WC_L]$. The matrix framed comprises numerical values in crisp form.

Step 6 : Determination of Score Values

The score values of the alternatives subjected to both beneficiary (Score_{Beneficiary}) and (Score_{non-Beneficiary}) non-beneficiary values are computed.

Step 7: Finding the ranks of the alternatives

The ranks of the alternatives are obtained with determination of the Score value. The alternative with maximum value is ranked first and so on.

The overall process of the methodology is described by using the fig.1.

Application to the Decisioning Problem

This section elucidates the proposed problem of ranking the alternative energy resources using different quantifications of the contradiction degrees.

Problem Description

Let us consider a manufacturing company which faces a decisioning situation of switching to alternate sources of energy. The company considers the criteria and the alternatives presented in the Table 1. The criterion values are presented in Table 2 to facilitate the decision makers in constructing an optimal ranking of the alternatives. The dominant criterion values are also presented in Table 3. The proposed approach in section 3 is applied to the above described decisioning problem. The above Table 1 comprises 10 alternatives and 8 criteria with a total of 24 criterion values. The decisioning matrix initially formulated to represent the association of the alternatives with the criteria is presented below in a tabular form with linguistic variable representations. The initial decisioning matrix is represented in Table 2. The dominant criterion values subjected to each of the criteria is presented in the Table 3. The contradiction degrees of the criterion values with respect to dominant criterion value or the attribute is presented as



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linguistic variables in Table 4. The quantification of the linguistic variable using different representations is presented in Table 5. The respective quantification of the linguistic variables using different representations is presented in Table 6. With the assumption of equal weight age to the criteria, the ranking of the alternatives is computed as follows for different quantifications under three cases.

Case (i) Fuzzy Quantification

The contradiction matrix after quantifying the linguistic variable using fuzzy triangular numbers and respective defuzzification is presented in tabular form as in Table 7. The weighted contradiction matrix with fuzzy quantification is presented in tabular form as in Table 8. The scores of the alternatives with respect to non-beneficiary (cost) and beneficiary criteria, their differences and final rankings are presented in Table 9.

Case (ii) Intuitionistic Quantification

The contradiction matrix after quantifying the linguistic variable using intuitionistic triangular numbers and respective defuzzification is presented in tabular form as in Table 10. The weighted contradiction matrix with intuitionistic quantification is presented in tabular form as in Table 11. The scores of the alternatives with respect to non-beneficiary (cost) and beneficiary criteria, their differences and final rankings are presented in Table 12.

Case (iii) Neutrosophic Quantification

The contradiction matrix after quantifying the linguistic variable using neutrosophic triangular numbers and respective defuzzification is presented in tabular form as in Table 13. The weighted contradiction matrix with neutrosophic quantification is presented in tabular form as in Table 14. The scores of the alternatives with respect to non-beneficiary (cost) and beneficiary criteria, their differences and final rankings are presented in Table 15.

Sensitivity Analysis

The ranking results obtained under three cases in the section 4 is compared with the conventional representation of the linguistic variable. The contradiction matrix in conventional form is presented in Table 16. The weighted contradiction matrix with equal criterion weightage is presented in Table 17. The scoring of the alternatives and the rankings are presented in Table 18. The score values of the alternatives obtained using conventional and different quantifications are presented in Table 19. The comparative analysis of the score values is presented graphically in Fig.2. From the figure and the tabulated values, it is observed that the alternatives A3 and A8 occupies most favorable ranking position. On other hand the alternatives A4,A5 and A9 occupies least favorable position in rankings whereas the other alternatives occupy mixed positions in ranking. The rankings obtained under three cases and the conventional from are compared using correlation and the results are presented in Table 20. The correlation coefficient between the rankings obtained using different quantifications and the conventional procedure is pictorially represented using heat maps as in Fig.3 The pair-wise comparisons between each of the ranking methods are presented in Fig. 4.

Inferences

From the above ranking results presented in Table 20, Fig 3 and 4, the following observations are made. The ranking results obtained using fuzzy, intuitionistic and neutrosophic are more consistent and reliable in comparison with the conventional method. The ranking results are more promising in the context of linguistic variable representation of contradiction degree than the usual procedure. The results obtained in section 4 and the sensitivity analysis in section 5 favours the linguistic variable representation of the contradiction degrees between the dominant attributes and other attribute values. Since the expert's opinion are subjective in nature, linguistic representations facilitate in formulating comprehensive decision process. However, in comparisons between fuzzy, intuitionistic and neutrosophic, the rankings obtained using neutrosophic quantifications are more promising as it is more closer to the conventional ranking results.





CONCLUSION

This research work presents a comparative analysis of the different quantifications of the linguistic variables. The application of plithogenic based decisioning with different quantifications of linguistic variable with special reference to the ranking of alternative energy resources is presented in this work. The linguistic representations of the contradiction degree is proposed in this research work and the efficacy of such representations are validated using different quantifications in the context of ranking alternative energy resources. This study shall be extended by using other kinds of quantifications. Also, comparative studies shall also be initiated to explore the efficiency of linguistic variable representations in decisioning.

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Table.1: Elements of Decisioning

Alternatives	Criteria	Criterion Values
Solar Power Generation	Cost (Non-Beneficiary)	Low, Moderate, High
Wind Power Generation	Energy Efficiency (Benefit)	Poor, Average, Excellent
Biomass Energy Generation	Environmental Impact (Non-Beneficiary)	Negligible, Moderate, Significant
Hydropower Generation	Reliability	Unreliable, Consistent, Highly Reliable
Geothermal Energy Generation	Flexibility & Scalability (Benefit)	Rigid, Expandable, Highly Flexible
Combined Heat and Power (CHP)	Technological Feasibility (Benefit)	Emerging, Proven, Advanced
Fuel Cells	Energy Security (Benefit)	Limited, Stable, Abundant
Micro-turbines		
Tidal Power Generation	Social Acceptance (Benefit)	Low support, Moderate support, High support
Hybrid Renewable Systems		

Table.2: Initial Decisioning Matrix

Alternative	Cost	Energy Efficiency	Environmental Impact	Reliability	Flexibility & Scalability	Technological Feasibility	Energy Security	Social Acceptance
Solar Power Generation (A1)	Moderate	Average	Moderate	Consistent	Expandable	Proven	Stable	High Support
Wind Power Generation (A2)	Moderate	Excellent	Moderate	Highly Reliable	Highly Flexible	Proven	Abundant	Moderate Support
Biomass Energy Generation	Low	Average	Significant	Consistent	Expandable	Emerging	Stable	Moderate Support
Hydropower	High	Excellent	Significant	Highly Reliable	Expandable	Advanced	Abundant	High Support





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Generation								
Geothermal Energy Generation	High	Excellent	Moderate	Consistent	Highly Flexible	Advanced	Abundant	High Support
Combined Heat and Power (CHP)	Moderate	Average	Moderate	Consistent	Expandable	Proven	Stable	Moderate Support
Fuel Cells	High	Average	Moderate	Consistent	Rigid	Emerging	Limited	Low Support
Micro-turbines	Low	Average	Negligible	Reliable	Rigid	Emerging	Limited	Low Support
Tidal Power Generation	High	Excellent	Significant	Highly Reliable	Highly Flexible	Advanced	Abundant	High Support
Hybrid Renewable Systems	Moderate	Excellent	Moderate	Consistent	Highly Flexible	Proven	Stable	High Support

Table.3:Dominant Criterion Value

Criteria	Dominant Criterion Value
Cost	Low
Energy Efficiency	Excellent
Environmental Impact	Significant
Reliability	Highly Reliable
Flexibility & Scalability	Highly Flexible
Technological Feasibility	Advanced
Energy Security	Abundant
Social Acceptance	High Support

Table.4:Contradiction degree wrt dominant attribute

Criteria	Cost	Energy Efficiency	Environmental Impact	Reliability	Flexibility & Scalability	Technological Feasibility	Energy Security	Social Acceptance
A1	M	M	M	M	M	M	M	0
A2	M	0	M	0	0	M	0	M
A3	0	M	0	M	M	H	M	M
A4	H	0	0	0	M	0	0	0
A5	H	0	M	M	0	0	0	0
A6	M	M	M	M	M	M	M	M
A7	H	M	M	M	H	H	H	H
A8	0	M	H	H	H	H	H	H
A9	H	0	0	0	0	0	0	0
A10	M	0	M	M	0	M	M	0





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Table.5:Different Representations of Linguistic Variables

Criteria	Distinct Criterion Levels	Fuzzy Triangular (FTN)	Intuitionistic Triangular (ITN)	Neutrosophic Triangular (NTN)
Cost	Low	(0,0.1,0.3)	((0.05, 0.15, 0.3),0.7,0.2)	((0.05, 0.15, 0.3), (0.4, 0.6, 0.8), (0.1, 0.2, 0.3))
	Moderate	(0.3,0.5,0.7)	((0.3, 0.5, 0.7), 0.5,0.3)	((0.3, 0.5, 0.7), (0.5, 0.7, 0.9), (0.2, 0.3, 0.5))
	High	(0.7,0.9,1)	((0.7, 0.85, 1), 0.2,0.6)	((0.7, 0.85, 1), (0.6, 0.8,1), (0.2, 0.3, 0.4))
Energy Efficiency	Poor	(0, 0.2, 0.4)	((0.1, 0.2, 0.4), 0.6,0.2)	((0.02, 0.12, 0.25), (0.35, 0.5, 0.7), (0.1, 0.15, 0.25))
	Average	(0.4, 0.6, 0.8)	((0.4, 0.6, 0.8), 0.4,0.5)	((0.35, 0.55, 0.75), (0.55, 0.75, 0.95), (0.25, 0.35, 0.55))
	Excellent	(0.8, 1, 1)	((0.8, 0.9, 1), 0.2,0.5)	((0.72, 0.87, 0.98), (0.64, 0.82, 1), (0.22, 0.3, 0.38))
Environmental Impact	Negligible	(0.2, 0.3, 0.4)	((0.05, 0.15, 0.3), 0.7,0.1)	((0.04, 0.14, 0.28), (0.3, 0.55, 0.75), (0.05, 0.1, 0.2))
	Moderate	(0.3, 0.6, 0.7)	((0.3, 0.5, 0.7), 0.4,0.5)	((0.28, 0.48, 0.68), (0.52, 0.72, 0.9), (0.22, 0.32, 0.45))
	Significant	(0.6, 0.8, 1)	((0.7, 0.85, 1), 0.2,0.5)	((0.68, 0.83, 0.96), (0.61, 0.79, 0.99), (0.19, 0.28, 0.37))
Reliability	Unreliable	(0.2, 0.4, 0.5)	((0.1, 0.2, 0.4), 0.6,0.2)	((0.03, 0.1, 0.22), (0.4, 0.65, 0.8), (0.12, 0.2, 0.32))
	Consistent	(0.5, 0.7, 0.9)	((0.4, 0.6, 0.8), 0.4,0.5)	((0.32, 0.5, 0.72), (0.6, 0.78, 0.98), (0.18, 0.28, 0.4))
	Highly Reliable	(0.8, 0.9, 1)	((0.8, 0.9, 1), 0.2,0.6)	((0.74, 0.88, 1), (0.67, 0.83, 1), (0.24, 0.32, 0.42))
Flexibility & Scalability	Rigid	(0, 0.2, 0.4)	((0.1, 0.2, 0.4), 0.6,0.2)	((0.05, 0.13, 0.26), (0.38, 0.52, 0.72), (0.09, 0.18, 0.27))
	Expandable	(0.4, 0.6, 0.8)	((0.4, 0.6, 0.8), 0.4,0.3)	((0.3, 0.47, 0.69), (0.53, 0.73, 0.92), (0.24, 0.34, 0.46))
	Highly Flexible	(0.8, 1, 1)	((0.8, 0.9, 1), 0.2,0.5)	((0.71, 0.86, 1), (0.65, 0.82, 1), (0.2, 0.3, 0.4))
Technological Feasibility	Emerging	(0.1, 0.3, 0.4)	((0.1, 0.2, 0.4), 0.7,0.2)	((0.01, 0.08, 0.2), (0.45, 0.6, 0.78), (0.07, 0.13, 0.21))
	Proven	(0.5, 0.6, 0.8)	((0.4, 0.6, 0.8), 0.4,0.5)	((0.31, 0.49, 0.7), (0.58, 0.74, 0.93), (0.2, 0.3, 0.44))
	Advanced	(0.8, 0.9, 1)	((0.8, 0.9, 1), 0.2,0.5)	((0.69, 0.84, 0.97), (0.63, 0.81, 1), (0.21, 0.31, 0.39))
Energy Security	Limited	(0, 0.2, 0.4)	((0.1, 0.2, 0.4), 0.7,0.1)	((0.03, 0.11, 0.24), (0.36, 0.55, 0.7), (0.08, 0.17, 0.26))
	Stable	(0.4, 0.7, 0.9)	((0.4, 0.6, 0.8), 0.4,0.5)	((0.27, 0.48, 0.7), (0.51, 0.72, 0.92), (0.23, 0.32, 0.48))
	Abundant	(0.7, 0.8, 1)	((0.8, 0.9, 1), 0.2,0.5)	((0.66, 0.82, 0.96), (0.62, 0.8, 1), (0.2, 0.29, 0.38))
Social	Low Support	(0.2, 0.3, 0.4)	((0.1, 0.3, 0.5), 0.6,0.2)	((0.04, 0.13, 0.25), (0.37, 0.5, 0.68),





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Acceptance				(0.06, 0.16, 0.23))
	Moderate Support	(0.4, 0.6, 0.7)	((0.4, 0.6, 0.8), 0.3,0.6)	((0.34, 0.55, 0.74), (0.53, 0.74, 0.95), (0.22, 0.31, 0.46))
	High Support	(0.7, 1, 1)	((0.8, 0.9, 1), 0.2,0.4)	((0.73, 0.86, 0.99), (0.68, 0.83, 1), (0.25, 0.33, 0.43))

Table.6: Different Quantifications of Linguistic Variables

Criteria	Distinct Criterion Levels	Fuzzy Triangular(FTN)	Intuitionistic Triangular (ITN)	Neutrosophic Triangular (NTN)
Cost	Low	0.1333	0.1673	0.3208
	Moderate	0.5	0.5214	0.5083
	High	0.8667	0.9063	0.65
Energy Efficiency	Poor	0.2	0.2243	0.2675
	Average	0.6	0.65	0.5583
	Excellent	0.9333	0.925	0.66
Environmental Impact	Negligible	0.3	0.1626	0.2667
	Moderate	0.5333	0.55	0.5075
	Significant	0.8	0.8875	0.6333
Reliability	Unreliable	0.3667	0.2243	0.3158
	Consistent	0.7	0.65	0.5267
	Highly Reliable	0.9	0.9375	0.6775
Flexibility & Scalability	Rigid	0.2	0.2243	0.2858
	Expandable	0.6	0.6214	0.5183
	Highly Flexible	0.9333	0.925	0.66
Technological Feasibility	Emerging	0.2667	0.2283	0.2783
	Proven	0.6333	0.65	0.5183
	Advanced	0.9	0.925	0.6508
Energy Security	Limited	0.2	0.2225	0.2775
	Stable	0.6667	0.65	0.5125
	Abundant	0.8333	0.925	0.6367
Social Acceptance	Low Support	0.3	0.3125	0.2675
	Moderate Support	0.5667	0.675	0.5367
	High Support	0.9	0.9167	0.6767

Table.7:Contradiction Matrix with fuzzy quantification

Crit eria	Cost (C)	Energy Efficiency (B)	Environmen tal Impact (C)	Reliabili ty (B)	Flexibility & Scalability (B)	Technological Feasibility (B)	Energy Security (B)	Social Acceptanc e(B)
A1	0.5	0.6	0.5333	0.7	0.6	0.6333	0.6667	0
A2	0.5	0	0.5333	0	0	0.6333	0	0.5667
A3	0	0.6	0	0.7	0.6	0.2667	0.6667	0.5667
A4	0.8667	0	0	0	0.6	0	0	0
A5	0.8667	0	0.5333	0.7	0	0	0	0
A6	0.5	0.6	0.5333	0.7	0.6	0.6333	0.6667	0.5667
A7	0.8667	0.6	0.5333	0.7	0.2	0.2667	0.2	0.3
A8	0	0.6	0.3	0.3667	0.2	0.2667	0.2	0.3
A9	0.8667	0	0	0	0	0	0	0
A10	0.5	0	0.5333	0.7	0	0.6333	0.6667	0





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Table.8:Weighted Contradiction Matrix with fuzzyquantification

Crit eria	Cost (C)	Energy Efficiency (B)	Environme ntal Impact (C)	Reliability (B)	Flexibility & Scalability (B)	Technological Feasibility (B)	Energy Security (B)	Social Acceptanc e(B)
A1	0.0625	0.075	0.0666	0.0875	0.075	0.0792	0.0833	0
A2	0.0625	0	0.0666	0	0	0.0792	0	0.0708
A3	0	0.075	0	0.0875	0.075	0.0334	0.0334	0.0708
A4	0.1083	0	0	0	0.075	0	0	0
A5	0.1083	0	0.0666	0.0875	0	0	0	0
A6	0.0625	0.075	0.0666	0.0875	0.075	0.0792	0.0334	0.0708
A7	0.1083	0.075	0.0666	0.0875	0.025	0.0334	0.025	0.0375
A8	0	0.075	0.0375	0.0458	0.025	0.0334	0.025	0.0375
A9	0.1083	0	0	0	0	0	0	0
A10	0.0625	0	0.0666	0.0875	0	0.0792	0.0334	0

Table.9:Fuzzy based Rankings of the Alternatives

Alternatives	Cost criteria	Benefit criteria	Differences in Score Values	Rankings of the alternatives
A1	0.1291	0.4	0.2709	3
A2	0.1291	0.15	0.0209	7
A3	0	0.3751	0.3751	1
A4	0.1083	0.075	-0.0333	8
A5	0.1749	0.0875	-0.0874	9
A6	0.1291	0.4209	0.2918	2
A7	0.1749	0.2834	0.1085	5
A8	0.0375	0.2417	0.2042	4
A9	0.1083	0	-0.1083	10
A10	0.1291	0.2001	0.071	6

Table.10:Contradiction matrix with Intuitionistic quantification

Criter ia	Cost	Energy Efficienc y	Environme ntal Impact	Reliability	Flexibility & Scalability	Technologic al Feasibility	Energy Security	Social Acceptance
A1	0.5214	0.65	0.55	0.65	0.6214	0.65	0.65	0
A2	0.5214	0	0.55	0	0	0.65	0	0.675
A3	0	0.65	0	0.65	0.6214	0.2283	0.65	0.675
A4	0.9063	0	0	0	0.6214	0	0	0
A5	0.9063	0	0.55	0.65	0	0	0	0
A6	0.5214	0.65	0.55	0.65	0.6214	0.65	0.65	0.675
A7	0.9063	0.65	0.55	0.65	0.2243	0.2283	0.2225	0.3125
A8	0	0.65	0.1626	0.2243	0.2243	0.2283	0.2225	0.3125
A9	0.9063	0	0	0	0	0	0	0
A10	0.5214	0	0.55	0.65	0	0.65	0.65	0





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Table.11:Weighted Contradiction matrix with Intuitionistic quantification

Crit eria (C)	Cost	Energy Efficiency (B)	Environmen tal Impact(C)	Reliability (B)	Flexibility & Scalability (B)	Technolo gical Feasibilit y (B)	Energy Security (B)	Social Acceptanc e(B)
A1	0.0652	0.0813	0.0688	0.0813	0.0777	0.0813	0.0813	0
A2	0.0652	0	0.0688	0	0	0.0813	0	0.0844
A3	0	0.0813	0	0.0813	0.0777	0.0285	0.0813	0.0844
A4	0.1133	0	0	0	0.0777	0	0	0
A5	0.1133	0	0.0688	0.0813	0	0	0	0
A6	0.0652	0.0813	0.0688	0.0813	0.0777	0.0813	0.0813	0.0844
A7	0.1133	0.0813	0.0688	0.0813	0.0280	0.0285	0.0278	0.0391
A8	0	0.0813	0.0280	0.0280	0.0280	0.0285	0.0278	0.0391
A9	0.1133	0	0	0	0	0	0	0
A10	0.0652	0	0.0688	0.0813	0	0.0813	0.0813	0

Table.12:Intuitionistic based Rankings of the Alternatives

Alternatives	Cost criteria	Benefit criteria	Differences in Score Values	Rankings of the alternatives
A1	0.134	0.4029	0.2689	3
A2	0.134	0.1657	0.0317	7
A3	0	0.4345	0.4345	1
A4	0.1133	0.0777	-0.0356	8
A5	0.1821	0.0813	-0.1008	9
A6	0.134	0.4873	0.3533	2
A7	0.1821	0.286	0.1039	6
A8	0.028	0.2327	0.2047	4
A9	0.1133	0	-0.1133	10
A10	0.134	0.2439	0.1099	5

Table.13:Contradiction Matrix with Neutrosophic Quantification

Criter ia	Cost	Energy Efficiency	Environmental Impact	Reliability	Flexibility & Scalability	Technologi cal Feasibility	Energy Security	Social Acceptan ce
A1	0.5083	0.5583	0.5075	0.5267	0.5183	0.5183	0.5125	0
A2	0.5083	0	0.5075	0	0	0.5183	0	0.5367
A3	0	0.5583	0	0.5267	0.5183	0.2783	0.5125	0.5367
A4	0.65	0	0	0	0.5183	0	0	0
A5	0.65	0	0.5075	0.5267	0	0	0	0
A6	0.5083	0.5583	0.5075	0.5267	0.5183	0.5183	0.5125	0.5367
A7	0.65	0.5583	0.5075	0.5267	0.2858	0.2783	0.2775	0.2675
A8	0	0.5583	0.2667	0.3158	0.2858	0.2783	0.2775	0.2675
A9	0.65	0	0	0	0	0	0	0
A10	0.5083	0	0.5075	0.5267	0	0.5183	0.5125	0





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Table.14:Weighted contradiction matrix with neutrosophic triangular

Crit eria	Cost (C)	Energy Efficiency (B)	Environmen tal Impact (C)	Reliability (B)	Flexibility & Scalability (B)	Technological Feasibility (B)	Energy Security (B)	Social Acceptanc e(B)
A1	0.0635	0.0698	0.0634	0.0658	0.0648	0.0648	0.0641	0
A2	0.0635	0	0.0634	0	0	0.0648	0	0.0671
A3	0	0.0698	0	0.0658	0.0648	0.0348	0.0641	0.0671
A4	0.0813	0	0	0	0.0648	0	0	0
A5	0.0813	0	0.0634	0.0658	0	0	0	0
A6	0.0635	0.0698	0.0634	0.0658	0.0648	0.0648	0.0641	0.0671
A7	0.0813	0.0698	0.0634	0.0658	0.0357	0.0348	0.0347	0.0334
A8	0	0.0698	0.0333	0.0395	0.0357	0.0348	0.0347	0.0334
A9	0.0813	0	0	0	0	0	0	0
A10	0.0635	0	0.0634	0.0658	0	0.0648	0.0641	0

Table.15:Neutrosophic based Rankings of the Alternatives

Alternatives	Cost criteria	Benefit criteria	Differences in Score Values	Rankings of the alternatives
A1	0.1269	0.3293	0.2024	4
A2	0.1269	0.1319	0.005	7
A3	0	0.3664	0.3664	1
A4	0.0813	0.0648	-0.0165	8
A5	0.1447	0.0658	-0.0789	9
A6	0.1269	0.3964	0.2695	2
A7	0.1447	0.2742	0.1295	5
A8	0.0333	0.2479	0.2146	3
A9	0.0813	0	-0.0813	10
A10	0.1269	0.1947	0.0678	6

Table.16:Conventional Contradiction Matrix

Crit eria	Cost (C)	Energy Efficienc y(B)	Environmental Impact (C)	Reliability (B)	Flexibility & Scalability (B)	Technological Feasibility(B)	Energy Security (B)	Social Acceptanc e (B)
A1	1/3	1/3	1/3	1/3	1/3	1/3	1/3	0
A2	1/3	0	1/3	0	0	1/3	0	1/3
A3	0	1/3	0	1/3	1/3	2/3	1/3	1/3
A4	2/3	0	0	0	1/3	0	0	0
A5	2/3	0	1/3	1/3	0	0	0	0
A6	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
A7	2/3	1/3	1/3	1/3	2/3	2/3	2/3	2/3
A8	0	1/3	2/3	2/3	2/3	2/3	2/3	2/3
A9	2/3	0	0	0	0	0	0	0
A10	1/3	0	1/3	1/3	0	1/3	1/3	0





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Table.17:Conventional Weighted Contradiction Matrix

Criteria	Cost (C)	Energy Efficiency (B)	Environmental Impact (C)	Reliability (B)	Flexibility & Scalability (B)	Technological Feasibility (B)	Energy Security (B)	Social Acceptance(B)
A1	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0
A2	0.0833	0	0.0833	0	0	0.0833	0	0.0833
A3	0	0.0833	0	0.0833	0.0833	0.1667	0.0833	0.0833
A4	0.1667	0	0	0	0.0833	0	0	0
A5	0.1667	0	0.0833	0.0833	0	0	0	0
A6	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833	0.0833
A7	0.1667	0.0833	0.0833	0.0833	0.1667	0.1667	0.1667	0.1667
A8	0	0.0833	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
A9	0.1667	0	0	0	0	0	0	0
A10	0.0833	0	0.0833	0.0833	0	0.0833	0.0833	0

Table.18:Conventional Rankings of the Alternatives

Alternatives	Cost criteria	Benefit criteria	Differences in Score Values	Rankings of the alternatives
A1	0.1666	0.4165	0.2498	5
A2	0.1666	0.1666	0	9
A3	0	0.5832	0.5832	3
A4	0.1667	0.0833	-0.0834	7
A5	0.25	0.0833	-0.1667	8
A6	0.1666	0.4998	0.3332	4
A7	0.25	0.8334	0.5834	2
A8	0.1667	0.9168	0.7501	1
A9	0.1667	0	-0.1667	8
A10	0.1666	0.2499	0.0833	6

Table.19:Comparison of the Score Values

Alternatives	Score Values			
	Fuzzy	Intuitionistic	Neutrosophic	Conventional
A1	0.2709	0.2689	0.2024	0.2498
A2	0.0209	0.0317	0.005	0
A3	0.3751	0.4345	0.3664	0.5832
A4	-0.0333	-0.0356	-0.0165	-0.0834
A5	-0.0874	-0.1008	-0.0789	-0.1667
A6	0.2918	0.3533	0.2695	0.3332
A7	0.1085	0.1039	0.1295	0.5834
A8	0.2042	0.2047	0.2146	0.7501
A9	-0.1083	-0.1133	-0.0813	-0.1667
A10	0.071	0.1099	0.0678	0.0833





Table.20:Comparisons of the Rankings

	Fuzzy	Intuitionistic	Neutrosophic	Conventional
Fuzzy	1	0.9878	0.9878	0.7404
Intuitionistic		1	0.9757	0.6870
Neutrosophic			1	0.7983
Conventional				1

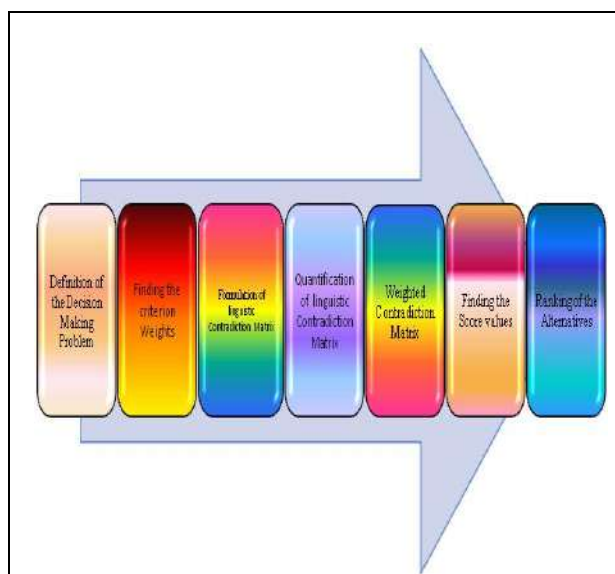


Figure.1:Decisioning Framework

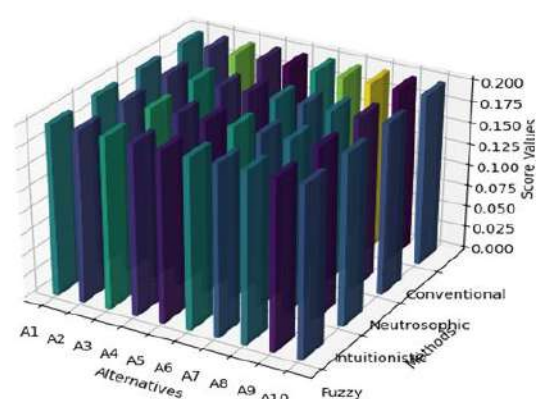


Figure.2:Analysis of Score Values

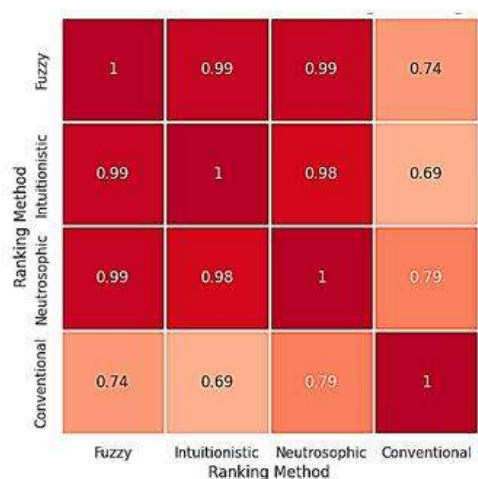


Figure. 3: Heat Maps representing the correlation between the Rankings

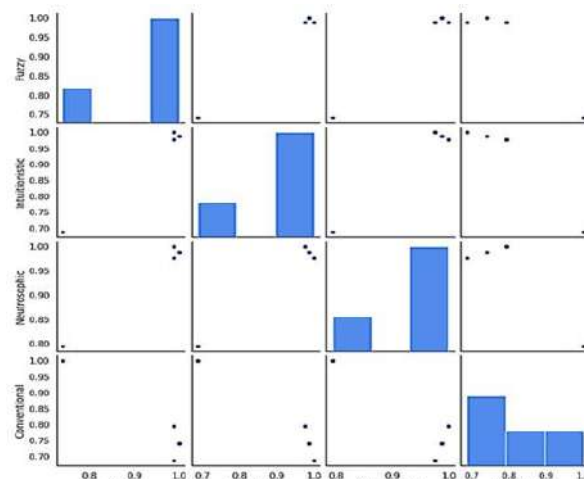


Figure. 4: Pair wise Comparison of Ranking Methods





Analysis on Key Components of Effective Micro-Mentoring - Employees Perspective

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ABSTRACT

The workplace development landscape is changing, and micro-mentoring is a crucial strategy for employee motivation and skill development. Organisational growth is also changing. Micro-mentoring is becoming more and more popular as a helpful tool for professional development and employee engagement. In the fast-paced workplaces of today, it remains an area that requires critical examination. While employee performance has been demonstrated to improve with typical mentoring methods, further research is necessary to completely comprehend the special impacts of micro-mentoring, which is distinguished by its focus and short duration. This study examines how micro-mentoring plays a significant role in employees in various industries. It focuses on understanding the differences in perceptions based on industry sectors and experience levels, aiming to identify significant factors that contribute to the success of micro-mentoring initiatives. The research highlights important aspects of micro-mentoring that greatly support employees' professional development and empowerment by carefully analysing the responses. This research employs a combination of quantitative analysis methodologies, including descriptive statistics, factor analysis, reliability testing (Cronbach's Alpha), ANOVA, and correlation analysis. The data were collected from 150 respondents across four sectors: manufacturing, information technology, service, and others, using a self-developed, pre-tested, and validated questionnaire. The results of this study examine the important aspects of micro-mentoring, identified are statistically significant indicating that it comprehends significant factors of micro-mentoring. It has been identified notable differences in how the workforce from various sectors view goal accomplishment and professional development within micro-mentoring, reflecting different priorities and needs across industries.

Keywords: Micro Mentoring, Components of Micro Mentoring, Professional Development, Goal Attainment & Employee perception





INTRODUCTION

The term "micro-mentoring" is a mentoring tactic in which mentees and mentors engage in brief, targeted conversations that usually span a few minutes up to a few hours. Micro-mentoring emphasizes short, focused exchanges of information, counsel, and direction as compared to traditional mentoring, which frequently entails longer-term relationships and formal arrangements (Chazot, C. A., L'Etoile, M., & Sandland, J. G. (2023)). It is a versatile and adaptable learning tool since it enables people to look for mentorship on subjects or difficulties as needed. Micro-mentoring fosters a variety of viewpoints and skill development and can take place in-house, among departments, or even in external networks (India employer forum, 2022). The dynamic learning demands of employees in today's fast-paced and constantly evolving workplace may pose a challenge for traditional mentoring programs. This innovative approach to mentoring fosters lifelong learning, cross-functional cooperation, and employee ownership of their own development on both a personal and professional level. As organizations increasingly embrace the principles of agility and flexibility, micro-mentoring emerges as a powerful tool for building a culture of learning and innovation, where every interaction becomes an opportunity for growth and development. Considering the current socio-emotional issues, it is crucial to modify mentoring techniques to suit the individual requirements and preferences of younger generations. (Saam Cook 2023) The systematic use of micro-mentoring as a professional development strategy may significantly enhance employee skills, motivation, and overall empowerment at work. The efficacy and impression of micro-mentoring, however, may differ throughout industries due to differences in organisational cultures, difficulties unique to a certain business, and demands about employee development. While preliminary factor analysis showed significant components of micro-mentoring that are appreciated in various industries, little is known about how employees prioritise and assess these aspects in various industrial situations. By performing a comparative investigation of employee perceptions and attitudes towards micro-mentoring across several industries, this study seeks to close this gap. This research will identify significant differences in the perception and efficacy of micro-mentoring components, with a focus on sector-specific nuances.

Based on the previous research and literature review the research will address the following research questions:

1. How does micro-mentoring contribute to employees' long-term career planning and skill development?
2. How successful is micro-mentoring in assisting employees in setting and achieving objectives?

This research will assess how the reliability and accuracy of the results by assessing the validity of the factor analysis carried out on the micro-mentoring components. Consequently, the research will address whether staff members' perceptions of the goal-achievement and professional development aspects of micro-mentoring vary significantly among industries. Our research will determine whether employees with different levels of experience have significantly different opinions on the goal-achievement and professional development aspects of micro-mentoring. The research will have great value in examining the relationships between each of the components of micro-mentoring and how they work together to support employees in the achievement of their goals and professional development.

REVIEW OF LITERATURE

Mentoring practices have become more prevalent in various fields. As per the 2021 Public Health Workforce Interests and Needs Survey, the management is becoming increasingly concerned with the rising levels of stress, burnout, and intent to resign among public health employees (Turgut, S., & Taşçi, G. (2024)). Research has shown that job fatigue can result from stressful work environments, which can hurt both mental and physical health. Few studies have indicated that personal coping strategies to alleviate the effects of stress are relatively understudied. A small number of studies have demonstrated that supervisors and workplace mentoring can be beneficial. Thus, research is needed to identify how micro-mentoring contributes to employees' long-term career planning and skill development. (Moruff Sanjo & OLADIMEJI (2020)) investigate how mentorship affects employees' performance in Nigeria's service sector. They employed regression analysis to examine the association in their investigation, which was founded on the 253 responses given by workers in the hotel industry. The authors concluded that adopting a mentoring function enhances worker performance and increases productivity.



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Shuang Xu (2021) emphasis the performance of mentors and how it affects their originality. The study concludes that, in addition to fostering the mentor's creativity, mentoring gives a business competitive edge. It enhances the mentor's ability to learn on their own in later career phases. This study used multiple regression analysis to determine the effect of mentorship on the creative performance of mentors, and confirmatory factor analysis to test the distinctiveness of variables collected from 153 responses from 15 enterprises in various provinces in China. **Sushmitha Srivastava & Jomon (2013)** examines how protégés' perceptions of relational and traditional mentoring support affect their role-based performance results. They also concluded that both forms of mentoring support had an impact on the protégé's role-based performance, with the protégé's own learning serving as a mediator. The author employed confirmatory factor analysis to check the dimensionality of the relational mentorship measures using 151 samples, demonstrating convergent validity, and correlation and regression analysis to evaluate the variables under research in this article. **VanBuskirk, A. (2023)** investigated how mentorship affected worker performance, the author found that coaching, apprenticeship training, and employee orientation all increased output. Training for apprenticeships also raised productivity. Employee performance was proxied by employee productivity, employee commitment, and organizational citizenship behaviour; in the context of this study, mentoring was divided into three categories: employee orientation, coaching, and apprenticeship. 336 responses were gathered by basic random sampling, and regression analysis was employed. **Adil Rasool & Mohammad Afzal Zarghoni (2021)** examined how employee growth is impacted by mentorship. As the authors investigated the relationship between employee productivity and mentorship, they recognized the obstacles and limitations. The study's sample comprised 700 workers at the CWSA office in Afghanistan. Multiple regression and bivariate correlation were used to determine the relationship between worker performance and mentoring, as well as how mentoring boosts worker productivity. **S.Chatterjee (2021)** examined the relationship between job performance and mentoring. The study also discovered that mentoring has several positive effects, such as enhanced job performance and career promotion, and that among Indian millennials, higher perceived mentoring may be linked to better perceived job performance. A multistage sampling technique was utilised to choose a sample of 123 millennial Indian employees who are mentored. Regression analysis and Structural equation modelling (SEM) was utilised to evaluate various models on the association between mentoring and job performance.

Perception of goal achievement on employee perspective

Van Beurden, J., Van De Voorde, K., & Van Veldhoven, M. (2022), This study provides an outline of existing research on employees' perceptions of HR procedures. It integrates the outcomes of several studies on employee behaviour and its effect on HR operations. It highlights the need to understand employees' perspectives to create effective HR policies that foster engagement and contentment. This article suggests future research initiatives to understand how HR practices and employee outcomes are associated. **Wei, F., Xu, L., Hu, X., Chang, S. C., & Wu, Y. (2023)**, The study uses goal-setting theory to investigate the impact of negative feedback on employee performance. This study employs a three-wave research design to determine whether an increase in negative feedback affects performance by reducing goal engagement. This negative effect is less likely to occur when employees have a growth mindset. This study demonstrates the power of negative feedback and therefore suggests a new way to manage ideas to improve performance. **Wang, W., Li, J., Sun, G., Cheng, Z., & Zhang, X. A. (2017)**, The study provides evidence that achievement goals can enhance life satisfaction, especially when combined with emotional regulation strategies. This contributes to understanding the consequences of achievement motivation and factors influencing well-being. Key findings focus on achieving goals which is positively related to life satisfaction and the perception of a successful agency that mediates the relationship between achievement goals and life satisfaction. An organization can boost its employee's motivation by inspiring them to achieve goals. Individuals must use emotional reappraisal when facing setbacks in goal pursuit. **Devarajan R, Maheshwari S & Vohra V. (2018)**, This study looks at how setting work goals affects how meaningful employees find their jobs, especially when work is changing a lot. It found that when employees understood why they were given certain goals, they felt their work was more meaningful. The study shows it's important for bosses to explain the reasons behind work goals. This can help employees feel better about their jobs, even when the way they work is changing. The main takeaway is that if companies want their workers to find their jobs meaningful, they should make sure to explain why each goal matters. **Maran T. K, Baldegger U & Klösel K. (2022)**, This research paper studies the effects of visionary leadership and empowering leadership on



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followers' goal achievement focusing on how these leadership styles influence their cognitive processes. The study emphasized on the importance of understanding how leader behaviors influence followers' cognitive processes.

Professional development in micro-mentoring on employee perspectives

St-JeanÉ & Tremblay, M. (2020), This study demonstrates that learning goal orientation (LGO) has a significant moderating influence on mentoring's enhancement of entrepreneurial self-efficacy in opportunity recognition (ESE-OR) among beginning entrepreneurs. While high LGO mentees enjoy a tempered effect, bringing self-efficacy in line with realistic levels, low LGO mentees gain more from mentoring, with enhanced ESE-OR. The study emphasizes how crucial mentors' roles and qualities are in fostering the growth of entrepreneurs. Notwithstanding these drawbacks, the results highlight how important LGO is to the success of entrepreneurs and offer insightful advice for enhancing mentoring initiatives. The study's robust methodology and longitudinal approach add significant depth to the understanding of mentoring outcomes. **RaginsB.R. & Kram K.E (2007)**, The evolution of mentoring over the past 25 years reflects significant paradigm shifts, including the emergence of peer, cross-gender, cross-cultural, and e-mentoring. These developments highlight the importance of recognizing diverse experiences and contexts in mentoring research. Key factors influencing effectiveness include personality, developmental stages, emotional intelligence, and relational skills. The critique of traditional benchmarks, particularly the focus on White male experiences, underscores the need for a broader perspective that incorporates diverse mentors' unique contributions. Emphasizing relational caches and personal development, the passage advocates for expanded, iterative research to better understand mentoring dynamics and outcomes across various contexts. **ShahM.H, Bin Othman A. R & Bin Mansor M.N(2016)**, Mentoring has gained prominence in SMEs due to its positive impact on business performance and employee development. It involves experienced mentors guiding less experienced individuals through phases of Initiation, Cultivation, Separation, and Redefinition. Mentoring offers career and psychosocial support, enhancing job satisfaction, confidence, and organizational outcomes. Despite its benefits—like improved productivity and reduced turnover—mentoring programs are not universally adopted.

Future research should focus on quantifying ROI and expanding mentoring practices in business contexts. **BarinuaV & IbeU.M. (2022)**, Mentoring, an ancient practice with modern applications, enhances personal and professional growth and organizational effectiveness. It encompasses informal mentoring, which evolves organically, formal mentoring with defined goals and trained mentors, and peer mentoring involving mutual support. Effective mentoring improves job satisfaction, reduces turnover, and boosts performance. Despite its benefits, adoption in Nigerian organizations is limited, though it offers potential solutions for youth unemployment and job dissatisfaction. **DugguhD.S.I, & Galadanchi A. M. (2014)**, This paper highlights the effectiveness of mentoring as a cost-effective employee training and development technique. It compares mentoring with traditional methods, emphasizing its benefits for the mentee, mentor and organization. Mentoring enhances organizational effectiveness and efficiency by improving employee skills, job satisfaction and retention. The paper recommends broader implementation of mentoring, alongside further research into related techniques like coaching and counseling, supported by a case study from Nottingham University. **RichardsonE. L, OetjenR, Oetjen D, Gordon J, Schroeder L. H, ConklinS & StrawnN. (2022)**, The introduction outlines higher education's challenges, worsened by the COVID-19 pandemic, including financial strain and enrollment issues. It highlights a shift from traditional to developmental advising, emphasizing competence, autonomy and career readiness. The text advocates for micro-advising and micro-mentoring, integrating career-focused activities within courses and using centralized advising and career centers. Incremental mentoring, including mentorship circles, is also emphasized. The conclusion stresses that combining centralized and decentralized approaches can enhance enrollment, retention, and career outcomes.

RESEARCH METHODOLOGY

To cross-reference the findings with empirical evidence, this study employed a combination of quantitative analysis methodologies. Its primary focus was on investigating the core components of micro-mentoring from the perspective of employees. The present study utilised a combination of quantitative analysis techniques to accomplish its goals.



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1. Firstly, descriptive statistics were employed to provide basic summaries about the sample and measures.
2. Factor analysis was applied to identify underlying relationships between variables and validate the components of micro-mentoring.
3. Reliability testing (e.g., Cronbach's Alpha) was carried out to assess the internal consistency of the components identified through factor analysis, ensuring the reliability of the questionnaire. RaykovT, MarcoulidesG, AnthonyJ & Menold N. (2024).
4. ANOVA was used to compare means and investigate whether there are significant differences in perceptions across different sectors or experience levels.
5. The relationships between the elements of micro-mentoring and how they work together to enhance employees' professional growth and goal achievement were examined using correlation analysis.

To collect a representative sample of workers from a range of industries and experience levels, surveys are an effective technique to gather information from a significant number of respondents. This technique enables the systematic collection of structured data, enabling quantitative comparison and analysis of responses. Respondents to questionnaires can remain anonymous, which encourages more truthful and precise answers, particularly when discussing delicate subjects like the efficacy of mentoring and employee professional growth. The survey method, especially the use of questionnaires, was adopted by the research scholar. Initially, 40 responses were collected to validate the questionnaire. To ensure that the survey instrument was reliable and accurately captured the desired components of micro-mentoring, this initial validation phase needed to be completed. Based on the comments from the pilot study, the questionnaire was improved. To determine the underlying structure of the items and validate the notions of goal accomplishment and professional development, factor analysis was employed. The main factors under investigation were the aspects of micro-mentoring that were focused on goal attainment and professional development. A structured questionnaire with Likert scale items (i.e., 1 = Strongly Disagree to 5 = Strongly Agree) was used to measure these factors. The perceptions of professional development and goal attainment were the dependent variables, and the industrial sector and employee experience level were the independent variables. Reviews by specialists were used to establish content validity, and pilot research was conducted to improve the questionnaire items to ensure the validity and reliability of the scales. The construct validity was verified by factor analysis and internal consistency was evaluated by calculating each scale's Cronbach's alpha (numbers above 0.70 signifying satisfactory reliability) Table I shows the reliability of Statistics. The Cronbach alpha value is .905 which is greater the 0.7 which shows that internal consistency of this scale is excellent

Analysis and Interpretation

In this study the data were collected from 150 respondents in four different sectors - manufacturing, information technology, service and others. Convenience sampling method was used for the sample, where four known individuals working in the respective sectors were asked to collect the survey responses from their colleagues and contacts. The initial goal was to collect 200 responses, 50 from each sector; however, only 150 were received, leading to different sample sizes in each area. As part of the research methodology, this study made use of research scholars self-developed, pre-tested and validated questionnaire to obtain data from the respondents. The questionnaire consists of two parts. The first part is on the demographic information of the respondents. The second part is the statement determining the key components of micro mentoring intended to elicit information about their perspectives and experiences with respect to their respective sectors. Because the participants in the convenience sampling approach were not chosen at random, there is a chance that biases may have been introduced into the sample, even if it made it easier to access a diverse range of respondents. However, the information gathered offers a useful overview of viewpoints and experiences from the different sectors.

Hypothesis Testing -1

The perseverance of the first objective is to ensure the methodological validity of the factor analysis employed in the research. This is to verify the components of micro-mentoring that have been found are reliable and appropriately represented for further research by validating the factor analysis. This involves examining the statistical measures such as Cronbach's alpha for reliability and performing factor analysis to verify the factor structure.



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H₀: The factor analysis is not valid

Factor analysis was carried out by using SPSS package for 150 respondents. The study shows the results of Bartlett's test of sphericity and KMO test. The table 2 shows the results of Bartlett's test of sphericity significance since the appropriate chi-square value is 1436.555 which is significant at 1% level, the test leads to the rejection of the null hypothesis therefore the hypothesis that the factor analysis is valid. The value of KMO statistics (.812) was also large and it reveals that factor analysis might be considered an appropriate technique for analysing the correlation matrix. This study formed 13 statements based on the key components of micro mentoring as shown in table 3, and from the table 4 based on the factor loadings the research scholar may conclude that the micro mentoring in the workplace is influenced by two major factors – Goal attainment, Professional Development

Hypothesis Testing -2

The second objective of this paper looks for variations in the way employees view the value of micro-mentoring based on the industry. The study aims to determine whether unique micro-mentoring approaches have a greater positive impact on certain companies by comparing perceptions from various sectors. This entails assessing if there are statistically significant variations in perceptions across industries using techniques like ANOVA.

H₀: There is no significant difference of opinion about the Goal attainment and professional development component of micro mentoring among employees from different sectors. Table 5 and Table 6 are the results of One-Way ANOVA analysis to determine the opinion of the employees about the goal attainment and professional development component of micro mentoring from different sectors. From the above tables the results reflect the p-value = **.001 < .05** which shows that the opinion of the employees from the different industrial sectors differs significantly and therefore the null hypothesis is accepted.

Hypothesis Testing -3

The drive of the third objective is to ascertain how employees' experiences affect and how they view micro-mentoring. The study offers insights into whether micro-mentoring needs to be adjusted differently for beginner versus experienced employees by examining differences in opinions based on experience. This is comparing perceptions across various experience levels using statistical test ANOVA

H₀: There is no significant difference of opinion about the Goal attainment and professional development component of micro mentoring among employees with different experience. Table 7 and table 8 are the results of One-Way ANOVA analysis to determine the opinion of the employees with different experience, about the goal attainment and professional development components of micro mentoring. From the above table 8 the results reflect the **p-value = .010 < .05** and table 7 the results reflect the **p-value = .012 < .05** which shows that the opinion of the employees with different experiences differs significantly (i.e.) the null hypothesis is accepted

Hypothesis Testing-4

The fourth objective is to investigate how the various components of micro-mentoring collaborate to encourage the overall professional growth and goals-achieving of employees. The study can determine which components of micro-mentoring are most important for success and how they work together to support employees by understanding these relationships. In order to examine the relationships between the components, correlation analysis is used.

H₀: There is no significant relationship between the goal attainment and professional development components of micro mentoring. From the table 9, the correlation coefficient of 0.707 indicates a strong positive relationship between professional development and goal attainment. The p-value of 0.001 is typically considered very low. This suggests that there is strong evidence to reject the null hypothesis that there is no correlation between professional development and goal attainment in the population. Therefore, the output indicates a strong positive correlation between professional development and goal attainment, which is statistically significant at a very low p-value. This suggests a meaningful relationship between the two variables, but further research would be needed to understand the nature of this relationship and any potential underlying factors.





RESULTS

The factor analysis's validation indicates that the key aspects of micro-mentoring that were found are trustworthy and statistically significant. This demonstrates how well it encompasses significant components of micro-mentoring. The notable significant differences in viewpoints among employees from various sectors about the components of goal accomplishment and professional development underscore the differing priorities or viewpoints among industries. Comprehending these distinctions can help develop customized micro-mentoring initiatives or interventions that more effectively address the requirements for employees across various industries. The major differences in viewpoints according to experience levels highlight how people's professional experiences shape their perspectives about the elements of micro-mentoring. This implies that expectations and choices about professional development and goal attainment within micro-mentoring programs are shaped to some extent by experience. The strong correlation seen among the constituents of micro-mentoring implies that these components are not discrete units but rather integrated facets of a unified mentoring structure. This suggests that modifications or enhancements to one element may have an impact on others, underscoring the significance of considering the whole character of micro-mentoring initiatives. Taking everything considered, these results offer insightful information to practitioners and organizations that are engaged in planning, carrying out, and overseeing micro-mentoring strategies. Organizations can customize their strategies to better suit the different requirements of their employees and optimize the effectiveness of mentoring interventions by recognizing the differences in views across sectors and experience levels, as well as the interconnectivity of micro-mentoring components.

CONCLUSION AND RESEARCH IMPLICATIONS

The study examined into the essential components of micro-mentoring and how important people with different backgrounds and experiences thought they were. Furthermore, we discovered notable differences in viewpoints according to the experience levels of the participants. These findings highlight how crucial it is to take individual backgrounds and sector-specific needs into account when creating micro-mentoring initiatives. Overall, our research offers insightful information to companies looking to improve their mentorship initiatives. Organisations can better address the needs of their employees and promote professional development and goal achievement across a range of industries and experience levels by customising their programmes based on an understanding of the interconnection and diversity of viewpoints among micro-mentoring components, Aryanti, I., & Perkasa, D. H. (2024). This research adds to the expanding corpus of knowledge on organisational development and mentorship, with useful implications for both policymakers and practitioners. This study has numerous practical implications for organizations that are interested in implementing or enhancing micro-mentoring programs. Supervisor can be trained to provide precise, actionable feedback and opportunities for frequent interactions can be created to enhance the professional development and goal achievement of employees.

Future scope for research

Future research needs to be conducted in the sector-specific intricacies of micro-mentoring. The long-term impact of micro-mentoring on organizational performance and career progression could be elucidated through longitudinal studies. Besides investigating the role of technology in facilitating micro-mentoring, particularly in remote work environments, could provide new opportunities to improve its efficacy. Comprehending the impact of various demographic variables, including age and experience level, on the perceptions of micro-mentoring can also assist in the customization of programs to meet the diverse requirements of the workforce.

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Table 1

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
.905	.907	13

Table 2

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.812
Bartlett's Test of Sphericity	Approx. Chi-Square	1436.555
	Df	78
	Sig.	<.001

Table 3

Sl. No	Statement determining the Key Components of Micro Mentoring
1	I get complete support and resources for my work
2	I get frequent guidance in reaching my objective
3	I actively pursue short-term mentoring to make sure I stay on path with my objectives
4	I will discuss about leveraging my skill for future
5	The guidance I receive from short, targeted mentoring sessions is valuable in assisting me in attaining my goals.





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6	I get appreciation for my work
7	I get guidance to succeed during challenges
8	I will reach my full potential
9	I receive direction in establishing my path for reaching both my personal and professional objectives
10	I receive advice when I need it to succeed in my career.
11	I always establish and accomplish goals with the help of guidance moments
12	I'm privileged to have access to clear instructions that support my long-term goals
13	A vital element of my success in achieving my goals is getting regular, focused advice

Table 4: Factor Loadings

Key Components of Micro Mentoring		Factors	Components	
			1	2
1	I get complete support and resources for my work	Goal Attainment (3.758)	0.777	
2	I get frequent guidance in reaching my objective		0.859	
3	I actively pursue short-term mentoring to make sure I stay on path with my objectives		0.731	
4	A vital element of my success in achieving my goals is getting regular, focused advice		0.564	
5	The guidance I receive from short, targeted mentoring sessions is valuable in assisting me in attaining my goals		0.827	
6	I will discuss about leveraging my skill for future	Professional Development (6.154)		0.895
7	I receive advice when I need it to succeed in my career			0.726
8	I receive direction in establishing my path for reaching both my personal and professional objectives			0.841
9	I always establish and accomplish goals with the help of guidance moments			0.641
10	I actively pursue short-term mentoring to make sure I stay on path with my objectives			0.706
11	I'm privileged to have access to clear instructions that support my long-term goals			0.793
12	I get guidance to succeed during challenges			0.708
13	I will reach my full potential			0.844

Table 5

Goal Attainment	ANOVA				
	Sum of Squares	df	Mean Square	F	Sig
Between the sectors	6.374	3	2.125	6.338	.001
Within the sectors	48.945	146	.335		
Total	55.319	149			

Table 6

Professional Development	ANOVA				
	Sum of Squares	df	Mean Square	F	Sig
Between the sectors	7.389	3	2.463	6.649	.001





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Within the sectors	54.077	146	.370		
Total	61.466	149			

Table 7

Goal Attainment	ANOVA				
	Sum of Squares	df	Mean Square	F	Sig
Between the experience level	3.995	3	1.332	3.788	.012
Within the experience level	51.324	146	.532		
Total	55.319	149			

Table 8

Professional Development	ANOVA				
	Sum of Squares	df	Mean Square	F	Sig
Between the experience levels	4.540	3	1.513	3.882	.010
Within the experience	56.926	146	.390		
Total	61.466	149			

Table 9

Correlations			
		Professional Development	Goal Attainment
Professional Development	Pearson Correlation	1	.707**
	Sig. (2-tailed)		.001
	N	150	150
Goal Attainment	Pearson Correlation	.707**	1
	Sig. (2-tailed)	.001	
	N	150	150

**Correlation is significant at the 0.01 level (2-tailed).





Thermal Performance Analysis of a Traditional Mud House: A Case Study in the Rural Fringe of Lucknow, India

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ABSTRACT

Mud houses have long been integral to the architectural landscape of rural India, valued for their affordability and eco-friendliness. This study conducts a detailed analysis of the thermal performance of a traditional mud house situated in the rural fringe area of Lucknow, India. The primary objective is to evaluate how effectively mud, a locally abundant building material, maintains thermal comfort, particularly under peak summer conditions. Constructed using clay and straw sourced from the local environment, mud houses in Lucknow's rural fringe demonstrate significant thermal inertia. This characteristic allows them to effectively buffer indoor temperature fluctuations. The study reveals that internal temperatures consistently remain 4-6°C cooler than external temperatures during hot weather. Furthermore, the relative humidity levels inside the mud house remain within the optimal comfort range, contributing to enhanced thermal comfort for residents. These findings highlight mud's natural insulating properties, which help reduce the reliance on artificial cooling systems. As a result, traditional mud houses represent a sustainable alternative to conventional construction methods, especially in warm climates. The study advocates for integrating traditional building materials like mud with modern construction techniques to enhance energy efficiency and occupant well-being. Future research should explore the long-term durability of mud houses in diverse climatic conditions and investigate potential design enhancements to further optimize thermal regulation.

Keywords: Mud House, Passive Design, Thermal Comfort, Local Materials, Sustainability





INTRODUCTION

India has a rich history of mud house construction, deeply rooted in its diverse climatic regions and cultural practices. Mud houses, also known as "kachcha" houses, have been a predominant form of rural housing for centuries. The Indus Valley Civilization, one of the world's oldest urban cultures, utilized mud bricks for constructing homes and public buildings, indicating the long-standing tradition of mud architecture in the Indian subcontinent [1]. In various parts of India, traditional mud houses vary in design and construction techniques, reflecting local adaptations to climatic conditions. For example, in the hot and arid regions of Rajasthan, mud houses often feature thick walls and small windows to minimize heat gain and maximize thermal mass. In contrast, in the humid regions of Kerala, mud houses are built with large overhangs and ventilated roofs to enhance airflow and reduce humidity levels [2]. The increasing global emphasis on sustainable and energy-efficient housing has spurred a renewed interest in traditional architectural practices. Among these, mud houses have garnered significant attention due to their low environmental impact, cost-effectiveness, and remarkable thermal performance. Historically prevalent in various cultures, these structures are particularly noted for their ability to maintain comfortable indoor temperatures in diverse climatic conditions. This study aims to conduct a comprehensive thermal performance analysis of a traditional mud house, exploring its potential as a viable solution for contemporary sustainable housing needs. Traditional mud houses are constructed using locally available materials such as earth, straw, and water, combined to form a durable and thermally efficient building material. The inherent properties of these materials, such as high thermal mass and low thermal conductivity, contribute to the unique thermal behavior of mud houses. Unlike modern construction materials that often require significant energy input for production and maintenance, mud houses offer a low-energy alternative with minimal carbon footprint [3]. Traditional mud houses are not only significant for their low construction costs and environmental benefits but also for their cultural and historical value. They represent a building technique that has evolved over generations, adapting to local climate conditions and resource availability. The thermal properties of mud have been extensively studied, with findings consistently showing that mud walls provide substantial thermal mass, which helps in maintaining stable indoor temperatures by absorbing and slowly releasing heat [4]. Extensive research has documented mud's insulating capabilities and thermal inertia, suggesting its potential to significantly reduce energy consumption and enhance occupant comfort [5] [6]. Mud's ability to provide insulation and thermal inertia has been documented in various studies, highlighting its potential to reduce energy consumption and enhance occupant comfort [7] [8]. This research seeks to quantify the thermal performance of a traditional mud house through empirical data collection and analysis. Understanding the performance of traditional mud houses under local climatic conditions is essential for promoting their integration into contemporary architectural and construction practices [9]. By examining the thermal performance, this research aims to provide valuable insights into the efficacy of mud houses in maintaining thermal comfort, reducing energy consumption, and promoting environmentally friendly construction practices. By examining the thermal dynamics of a specific mud house in Lucknow's rural context, this study aims to contribute empirical data to the broader discourse on sustainable building practices. Understanding the performance of traditional mud houses under local climatic conditions is essential for promoting their integration into contemporary architectural and construction practices [9].

Study Area

Anchramau, a village situated on Kursi Road on the rural fringe of Lucknow, serves as an intriguing site for analyzing thermal comfort within traditional vernacular architecture. The village's architectural landscape, marked by a blend of kaccha (temporary) and pakka (permanent) structures, offers a rich context for studying how indigenous building practices can create comfortable living environments in response to local climatic conditions. The climate of Lucknow is characterized by substantial seasonal variation and consistently high temperatures throughout the year shown in figure 1 and Table 1. Temperatures typically range from 8°C to 40°C, with rare occurrences falling below 5°C or exceeding 44°C. The hot season, extending from April 6 to June 26, spans approximately 2.7 months, during which average daily maximum temperatures exceed 36°C, peaking in June with highs of 38°C and lows of 27°C. Conversely, the cool season, lasting from December 7 to February 10, averages daily



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maximum temperatures below 25°C, with January being the coldest month, featuring temperatures from 9°C to 22°C. Humidity levels are notably high during the muggier period from May 9 to October 29, characterized by conditions that are muggy, oppressive, or miserable at least 25% of the time. August records the highest frequency of muggy days, totaling 31.0 days, while January experiences the fewest, with only 0.1 muggy days. Wind patterns also vary seasonally; the windier period, from January 21 to September 14, sees average hourly wind speeds above 2.8 meters per second, with June being the windiest month at 3.6 meters per second. The calmer period, spanning from September 14 to January 21, features lower wind speeds, with October being the calmest month, averaging 2.1 meters per second. Table 2 gives the climate modification strategies for composite climate regions. The village is composed of a cluster of mud houses that are constructed using locally-sourced materials such as brick, mud-clay, husk, and wood. These materials are not just culturally significant but are also highly functional, contributing to the thermal performance of the buildings. These structures, with their thick mud-clay walls, high ceilings, and ventilated roofs, are designed to maintain a stable indoor environment despite the external climatic fluctuations. The layout often includes shaded verandas and strategically oriented windows to optimize ventilation and minimize heat gain. The spatial arrangement of the houses in a cluster with a shared courtyard promotes airflow and provides communal spaces that remain cool even during the hottest months. The houses are oriented along an east-west axis to minimize direct solar exposure. For this research, one particular mud house from the cluster, known as "Mud House 1," has been selected as the focus for thermal comfort analysis shown in figure 2 and 3. This house is a representative example of the vernacular architecture in the region and embodies the principles that make these structures thermally efficient. This analysis will contribute to the broader discourse on sustainable architecture, showcasing how the wisdom embedded in traditional construction techniques can inform contemporary building practices, especially in regions where climate resilience is crucial.

The type of mud-house construction employed in and around Lucknow utilizes traditional earthen techniques adapted to local conditions. The primary method involves using a mixture of clay, sand, and straw, applied in layers to create robust walls. The construction process starts with preparing a stable foundation using stones or bricks to prevent moisture infiltration. The walls are built by layering the mud mixture over a bamboo or wooden frame, which provides both strength and insulation. The walls are typically around 300-450 mm thick [10]. The roofs generally feature a bamboo or wooden framework covered with thatch, tiles, or corrugated sheets. The thatch is made from local materials such as grass and palm leaves, which are woven together and laid over the roof structure. This roofing material provides effective insulation and protects against rain. The thatched roofs are known for their durability and can last up to 30 years with proper maintenance [11]. These mud houses are often built by local families with assistance from neighbors, reflecting a communal approach to construction. The use of readily available materials and traditional techniques allows these homes to blend seamlessly with their environment, showcasing a sustainable and practical response to local climatic and material conditions [12].

RESEARCH METHODS

This research is a case study involving both qualitative and quantitative approaches to evaluate the thermal performance of a traditional mud dwelling. It falls under the category of applied research, specifically in the fields of architectural science, environmental engineering, and sustainable building practices. The objective of this article is to evaluate the thermal performance of the mud dwelling, the research methodology involved both quantitative and qualitative data collection. Temperature measurements were recorded using thermal sensors installed at indoor location, while outdoor temperature was measured to assess the impact of solar exposure and wind direction. Continuous monitoring was facilitated by data loggers, providing comprehensive temperature data for April 29, 2024 (summer season) and Jan 9, 2024 (winter season). In addition to temperature measurements, questionnaires were administered to the inhabitants of the mud house to gather subjective assessments of thermal comfort. The questionnaires focused on daily activities, perceived indoor temperature variations, seasonal comfort levels, and adaptive behaviors for maintaining thermal comfort. In conclusion, the traditional mud dwelling on Kursi Road in Anchramau Village provides an exemplary study area for investigating the thermal performance of mud houses. This



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research, through meticulous data collection and analysis, offers valuable insights into the thermal comfort and energy efficiency of traditional mud houses, advocating for their preservation and enhancement amidst contemporary climate change and energy conservation challenges.

SURVEY FINDINGS AND DISCUSSION

The temperature data recorded for the traditional mud dwelling in Behta Village, Lucknow, on April 29, 2024 and January 9, 2024, demonstrates distinct variations in indoor and outdoor temperatures over a 24-hour period. The purpose is to study and analyze the thermal conditions during summer and winter season in mud dwellings of composite climate.

Temperature and Humidity recorded during summer season

The temperature and humidity data recorded on April 29, 2024 from the mud house on Kursi Road in Lucknow shown in figure 4 and 5 offers valuable insights into the thermal behavior of traditional mud construction during the summer season. Key observations include:

- **Temperature Stability:** Despite external temperatures peaking at 38°C, the internal temperature of the mud house remained relatively stable, fluctuating between 29.3°C and 29.9°C. This stability is attributed to the mud walls' capacity to absorb and store heat slowly, preventing rapid internal temperature increases. The mud's high density and specific heat capacity contribute to its ability to moderate temperature changes.
- **Temperature Lag:** In the cooler early morning hours, with external temperatures ranging from 24.3°C to 27.7°C, the interior was warmer by +1.8°C to +5.2°C. As the day progressed and external temperatures rose above 30°C, the internal temperature became cooler, with differences reaching as low as -8.5°C. This time lag, caused by the thermal mass of the mud walls, results in a natural cooling effect inside the house during the hottest parts of the day.
- **Thermal Conductivity:** The mud walls exhibit low thermal conductivity, providing significant thermal resistance due to their thickness. This characteristic slows down the rate at which heat penetrates from the outside to the inside, helping maintain a stable internal temperature despite significant external temperature fluctuations.
- **Humidity Regulation:** The hygroscopic nature of mud allows it to absorb and release moisture, which helps regulate indoor humidity levels. This property, combined with the thermal resistance, makes mud houses well-suited for climates with high temperature variations, such as Lucknow.

Temperature and Humidity recorded during winter season

The temperature and relative humidity data shown in figure 6 and 7 from the winter season offers insights into the thermal performance of the mud house. Key observations of the survey done on January 9, 2024 are as follows:

- **Temperature Stability:** Despite external temperatures fluctuating between 6.5°C and 17°C, the internal temperature remained stable, ranging from 13.6°C to 14.3°C. The mud walls' thermal mass plays a crucial role in moderating indoor temperatures by gradually absorbing and releasing heat.
- **Temperature Differences:** During early morning and evening hours, when external temperatures were between 6.5°C and 11.9°C, the interior was warmer by up to 7.3°C. This indicates the mud walls' effective thermal resistance and insulating properties, which prevent heat loss and maintain a warmer indoor environment.
- **Temperature Lag:** As external temperatures rose above 15°C during the day, the internal temperature difference became negative, reaching as low as -2.9°C. This occurs because the mud walls, after absorbing heat during cooler periods, gradually release it, keeping the interior cooler than the outside. The observed time lag highlights the high thermal mass of the mud.
- **Thermal Conductivity:** The low thermal conductivity of mud walls contributes to maintaining warmth inside the house, especially during the colder early morning hours. The mud's porous structure traps air, enhancing insulation and contributing to a stable indoor climate.
- **Effective Heat Distribution:** The thick walls of the mud house ensure effective heat distribution and retention, preventing cold spots and maintaining a uniform indoor temperature. Even with rising outside temperatures, the internal temperature remains relatively comfortable due to the gradual release of stored heat.





CONCLUSION

The thermal performance analysis of a traditional mud dwelling in Behta Village, Lucknow, conducted during the summer and winter seasons of 2024, underscores the effectiveness of mud houses in moderating indoor temperatures in a composite climate. The study reveals that, even when external temperatures soared to 38°C during the summer, the internal temperatures of the mud house remained stable, fluctuating between 29.3°C and 29.9°C. This temperature stability is primarily due to the high thermal mass of the mud walls, which absorb heat slowly and release it gradually, creating a natural cooling effect within the house. The temperature lag observed, where the interior was cooler than the exterior during the hottest part of the day, highlights the mud's ability to moderate indoor conditions without the need for mechanical cooling systems. However, despite these advantages, there is still a need to further reduce indoor temperatures during peak summer periods to enhance thermal comfort. To lower the temperature in mud houses during the summer, several recommendations can be made. First, increasing the thickness of the roof insulation can significantly reduce heat gain from the roof, which is often a major source of heat ingress. Second, incorporating shading devices such as verandas, overhangs, or green cover (trees and plants) around the dwelling can minimize direct solar radiation on the walls, thereby reducing the overall heat load on the structure. Third, optimizing ventilation by strategically placing windows and ventilators can enhance air circulation, allowing hot air to escape and cooler air to enter, thus maintaining a lower indoor temperature. During the winter, the internal temperature of the mud house remained stable between 13.6°C and 14.3°C, despite external temperatures fluctuating between 6.5°C and 17°C. This stability, coupled with the positive temperature differences during early morning and evening hours, highlights the effective thermal insulation properties of mud. The discomfort hours calculated from the data suggest that the mud house provides a comfortable living environment for most of the day across both summer and winter seasons shown in figure 8, reducing the reliance on artificial heating and cooling systems. Future studies could explore the long-term thermal performance of mud houses under varying climatic conditions and the integration of modern passive cooling strategies with traditional construction techniques. Investigating the use of natural materials and advanced architectural designs to further enhance the thermal comfort of mud houses could provide valuable insights for sustainable housing in regions with similar climates. Moreover, assessing the impact of these recommended interventions on discomfort hours during extreme weather conditions would contribute to developing more efficient and sustainable building practices.

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Table.1: Weather data, Lucknow; Source: Weather Spark.com

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature Average high °C	22	25	32	37	39	38	34	33	33	32	28	23
Temperature Average low °C	9	12	16	22	26	27	27	26	25	20	14	10
Relative Humidity %	80.1	70.1	53.5	45.6	51.7	62.4	81.8	86.1	80.7	66.3	69.8	74.6
Precipitation mm	13.9	15	6.8	7.6	21	102.1	226.4	204.9	148.1	36.5	4.8	7.8

Table.2: Climate Modification Strategies And Building Tactics For Composite Climate Type

Climate Type	Adverse Climatic Elements	Climate Method	Response Strategies
Composite	High heat during summers Low temperatures during winters Moderate to high humidity during monsoons.	Minimize heat gain in summers Maximize heat gain in winters Facilitate cross	1. Orientation to maximize benefits from seasonal sun angles. 2. Use of thermal mass for temperature regulation. 3. Adjustable shading devices like





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	Significant seasonal variations	ventilation during monsoons. Provide adjustable shading	louvers and blinds. 4. Operable windows for controlled ventilation. 5. Insulated walls and roofs to reduce heat transfer. 6. Verandas and overhangs for outdoor shading adaptable to seasons.
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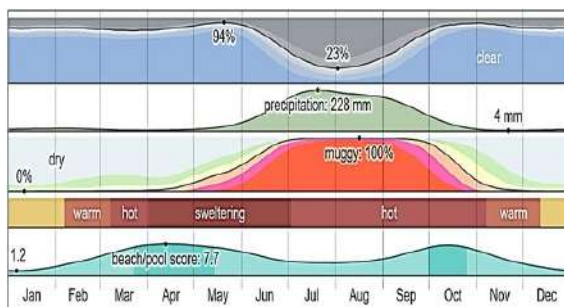


Figure.1: Weather chart, Lucknow; Source: Weather Spark.com

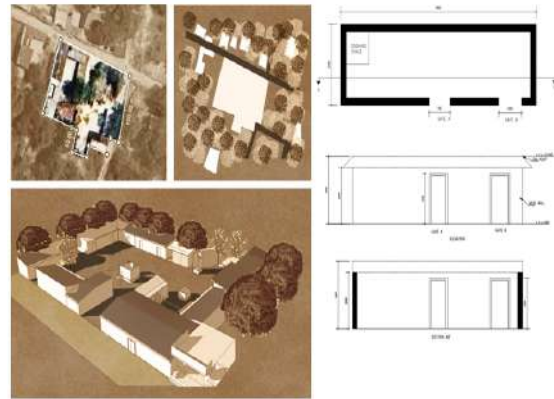


Figure.2: Mud house at Anchramau Village, Lucknow



Figure.3: Pictures of Mud House at Anchramau Village





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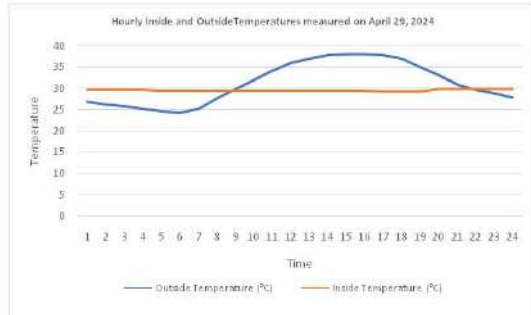


Figure.4: Hourly inside and outside Temperature measured on April 29, 2024

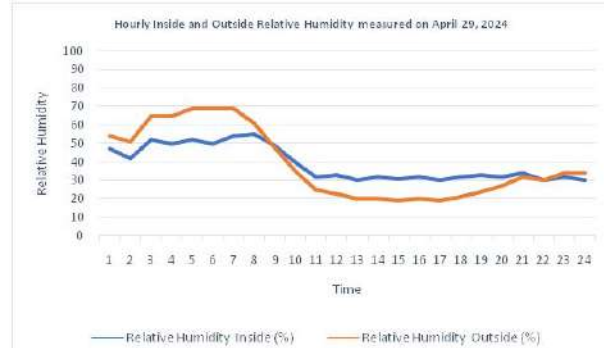


Figure.5: Hourly inside and outside Relative Humidity measured on April 29, 2024

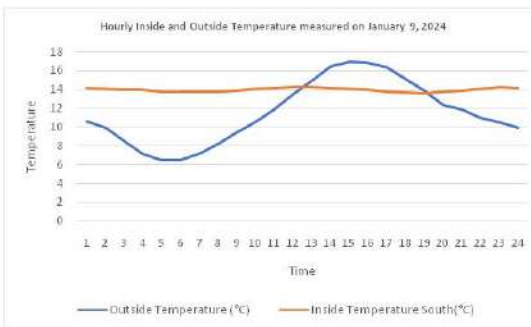


Figure.6:Hourly inside and outside Temperature measured on January 9, 2024

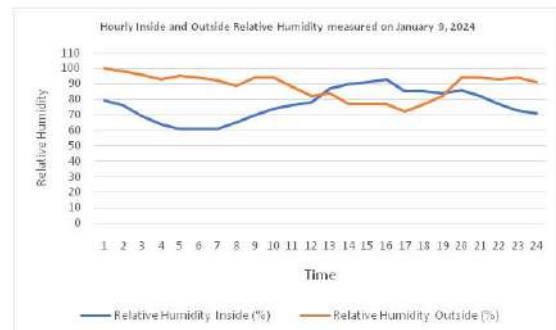


Figure.7:Hourly inside and outside Relative Humidity measured on January 9, 2024

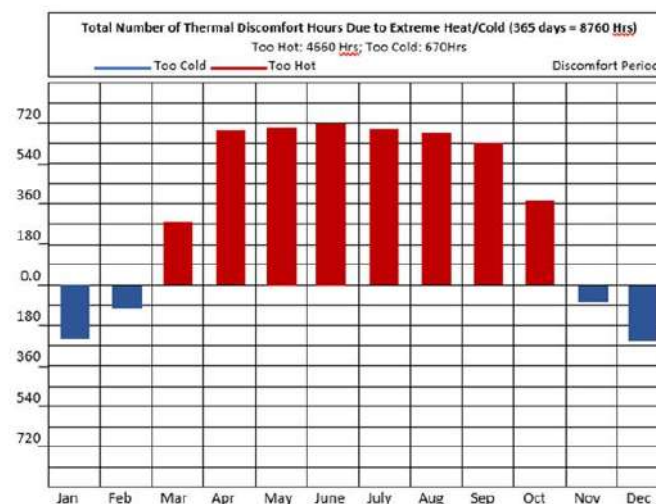


Figure.8:Detailed number of discomfort hours through the day (summer and winter) for mud house





Ayurvedic Therapeutic Approach in the Management of Chronic Venous Ulcer: A Case Report

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ABSTRACT

Chronic venous ulcers are a common condition resulting from venous insufficiency, often difficult to treat due to poor circulation and delayed healing. This case study outlines the Ayurvedic therapeutic approach in the management of a 45-year-old male patient with a chronic non-healing venous ulcer located on the left ankle. The patient received a combination of oral medications, local applications, Basti karma (medicated enema), and Jalauka Avacharan (leech therapy) based on classical Ayurvedic protocols. A holistic treatment plan targeting wound healing and venous circulation was implemented, with significant improvements observed in the wound's condition.

Keywords: Ayurvedic treatment, Basti therapy, Jatyadi Taila, Leech therapy (Jalauka Avacharan), Venous ulcer, Wound healing

INTRODUCTION

Venous ulcers are characterized by shallow, irregularly shaped wounds with surrounding skin discoloration, often reddish-brown, accompanied by symptoms such as swelling (edema), aching, and a sensation of heaviness in the legs. These ulcers may produce significant fluid discharge and are prone to infection, which can further delay healing. The management of venous ulcers typically involves a combination of strategies aimed at promoting healing and preventing recurrence. The cornerstone of conventional treatment is compression therapy, which helps reduce venous pressure and improve blood circulation. Effective wound care—encompassing regular cleaning, debridement and appropriate dressings—is also essential to prevent infection and support the healing process. In *Ayurveda*, venous ulcers, referred to as "*Dushta Vrana*," are managed through a holistic approach that addresses both the local

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wound and systemic imbalances. Key Ayurvedic interventions include Raktamokshana (bloodletting), often using leeches (Jalauka Avacharan), to alleviate venous congestion and reduce inflammation. Herbal formulations are applied locally for their wound-healing properties, while internal medications help detoxify the body and promote recovery. Regular cleaning of the wound (Vrana Prakshalana) with antiseptic decoctions, followed by dressing with medicated oils or pastes, is an integral part of this protocol. This integrative approach not only enhances wound healing but also helps prevent ulcer recurrence. Ayurvedic management of venous ulcers combines both local and systemic treatments, focusing on wound healing, reducing inflammation, and addressing underlying imbalances. One of the significant therapies is Basti (medicated enema), particularly designed to balance the aggravated doshas and improve overall systemic health. The ingredients used in this treatment are known for their blood-purifying properties, while other components aid in cleansing the channels and reducing inflammation. This dual approach—working both locally and systemically—promotes comprehensive healing and prevents recurrence. This case report highlights the application of Ayurvedic principles in managing a venous ulcer, emphasizing both local and systemic treatments, including Basti therapy and Jalauka Avacharan. The case demonstrates how this integrative approach can lead to effective healing of chronic venous ulcers.

Case Report

A 45-year-old male patient presented with a non-healing wound over his left ankle for the past month, along with localized swelling and a history of varicose veins in both lower limbs. The wound had developed gradually and showed little improvement since its appearance. Notably, the patient did not report any fever, significant pain, or discharge from the wound, which suggested a relatively stable condition despite its persistence. His medical history was free from major conditions such as diabetes mellitus, hypertension, or any known addictions, all of which are commonly associated with delayed wound healing. In terms of personal habits, the patient followed a vegetarian diet, had regular bowel movements, experienced sound sleep, and exhibited normal urinary frequency, voiding five to six times during the day and once at night. The *Rogi Pariksha*, or patient assessment, revealed that the patient's constitution (*Prakruti*) was predominantly *vata-pitta*. Other evaluations showed that his overall vitality (*Sarataha*) was moderate (*Madhyam*), as was his capacity for tissue resilience (*Sanhananataha*), body measurements (*Pramanataha*), mental stability (*Satwataha*), suitability of his environment (*Satmyataha*), dietary strength (*Ahara Shakti*), and physical activity levels (*Vyayamataha*). His age (*Vaya*) was assessed as moderate (*Madhyam*), and his tongue examination (*Jihwa*) appeared normal (*Niram*), further supporting the absence of systemic illness. Upon general examination, the patient demonstrated an abnormal gait, likely due to the discomfort from the wound and localized swelling. He was lying in a supine position during the examination. The patient displayed no signs of systemic illness, as indicated by the absence of pallor, icterus, cyanosis, edema, or lymph node enlargement. His vital signs were within normal limits, with a blood pressure reading of 128/76 mmHg, a pulse rate of 77 beats per minute, a respiratory rate of 17 breaths per minute, and a body temperature of 98.2°F.

A thorough clinical examination of the varicose veins was conducted, revealing dilated and tortuous veins in both lower limbs, particularly in the medial aspect of the legs and around the ankles. The patient exhibited signs of chronic venous insufficiency, characterized by skin changes such as hyper pigmentation and dryness, along with palpable veins that were not compressible, indicating venous stasis. Upon palpation, there was no tenderness along the affected veins. During the local examination, two distinct ulcers were observed on the anterior aspect of the lower leg, near the ankle. The larger ulcer measured 3x2 cm, and the smaller ulcer measured 1x1 cm. Both wounds were irregular in shape, with the larger ulcer having undermined and irregular edges, while the smaller one had slightly elevated and irregular edges. The depth of both ulcers was superficial, extending into the dermis, without evidence of deeper tissue involvement. Surrounding the wounds, the skin was darkened and hyper pigmented, with notable scaling and dryness, which are signs commonly associated with chronic venous insufficiency and varicose veins. In addition, the patient's bilateral varicose veins were contributing to venous congestion, further complicating the ulcer's healing process. Despite these findings, there was no active discharge or signs of acute infection, such as erythema or excessive swelling. However, the patient did report mild to moderate pain, which is consistent with the symptoms of chronic venous ulcers and varicose veins.



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Pathological investigations revealed a hemoglobin level of 11.6 gms%, a total red blood cell (RBC) count of 3.9 million/cmm, a total white blood cell (WBC) count of 5400/cumm, and a platelet count of 290,000/cmm. The patient's bleeding time was recorded as 1 minute and 33 seconds, and the clotting time was 3 minutes and 56 seconds, both of which were within normal limits. His random blood sugar (RBS) level was 116.4 mg/dl, indicating that his blood glucose was under control, which is critical for wound healing. Tests for infectious diseases, including HIV, VDRL (for syphilis), and HBsAg (for hepatitis B), were all negative, further ruling out any systemic infections. Based on the clinical findings and investigation results, the patient was diagnosed with a venous ulcer, complicated by underlying varicose veins. Thus the patient has been diagnosed with venous ulcer.

Treatment Protocol

The treatment protocol for the patient diagnosed with a venous ulcer involved a multi-faceted approach to ensure effective management and healing. Local Treatment consisted of daily wound dressing using *Jatyadi Taila*, a medicated oil renowned for its wound-healing properties, which helped create an optimal environment for recovery while protecting the wound from external contaminants. For Oral Medications, the patient took *Eladi Vati*, prescribed at a dosage of 2 tablets twice a day after meals, which supported metabolic function; *Nimbadi Vati*, also at 2 tablets twice a day after meals, which aided in detoxification; and *Giloy Ghanvati*, given at the same dosage, known for its immune-boosting qualities. In addition to these, a Para-Surgical Intervention was implemented through *Jalauka Avacharan*, with two sessions of leech therapy, applying two leeches during each session to enhance local circulation and facilitate healing. The treatment plan also included *Basti* Therapy, focusing on both local and systemic balance through a structured schedule alternating between *Niruha Basti* (*Manjishtadi Kshara Basti*) and *Anuvasan Basti*.

Method of Preparation of Manjishtadi Kshara Basti To prepare Manjishtadi Kshara Basti, the ingredients are mixed in the following order: First, 80 ml of honey and 8 g of rock salt (*Sandhava Lavana*) are blended uniformly using a *Khalva Yantra*. Next, 60 ml of processed *Ksheerbala taila* is added to form a uniform mixture. Then, 20 g of herbal paste (*Kalka*) made from *Shatpushpa* and *Yastimadhu* (20g) is incorporated. This is followed by adding 100 ml of decoction (*Kwatha*) prepared from the powdered herbs (*Kwatha Choorna*) of the *Manjistadhi*, *Yastimadhu*, *Guduchi*. Finally, 80 ml of *Gomutra arka* are added to achieve a homogenous mixture before testing for the appropriate *Nirooha Lakshana* (enema suitability). Administration of *Manjishtadi Kshara Basti* The prepared *Basti Dravya* was filtered and administered after being gently warmed using indirect heat. The specific sequence in which the ingredients were mixed ensured a uniform and properly combined solution. The total volume of the *Basti Dravya* was maintained at approximately 480 ml.

*N – *Niruha Basti*

A - *Anuvashan Basti*

- *Niruha Basti* is administered on an empty stomach in the morning.
- *Anuvasan Basti* is given after lunch.

DISCUSSION

This case demonstrates the effective management of a venous ulcer using a combination of *Ayurvedic* treatments, including local wound care, oral medications, and para-surgical interventions like leech therapy and *Basti* (medicated enema).

- **Local Treatment:** The use of *Jatyadi Taila* for daily dressing is well-supported in *Ayurveda* for its wound-healing properties, reducing inflammation, and promoting tissue regeneration.
- **Oral Medications:**
 - *Eladi Vati* and *Nimbadi Vati* have anti-inflammatory and antimicrobial properties, which help prevent infection and reduce inflammation.
 - *Giloy Ghanvati* is known for its immunomodulatory effects, enhancing the body's natural healing processes.





Constituents of Leech Saliva and Mode of Action of *Jalaukavacharana*

Leeches thrive in cold environments and possess a *Madhur* (sweet) taste, making them particularly effective for treating disorders related to aggravated *Pitta* and *Rakta*. The medicinal benefits of leech therapy, or *Jalaukavacharana*, arise from the bioactive compounds found in their saliva. These substances have anaesthetic, anti-inflammatory, anticoagulant, and vasodilating properties. These actions make the leech's bite painless, promote blood flow, reduce inflammation and edema, enhance fluid absorption, and aid in wound healing. Leeches draw impure blood from affected capillaries, which improves circulation and supports healing. Key bioactive substances in leech saliva include:

1. **Hirudin:** An antithrombotic agent that prevents blood clotting, promoting better blood flow and preventing blockages. This makes leech therapy useful in treating thromboembolic conditions like angina and atherosclerosis.
2. **Calin:** Inhibits blood coagulation by blocking the von Willebrand factor from binding to collagen, preventing platelet aggregation. It ensures continuous wound cleansing by prolonging secondary bleeding.
3. **Hyaluronidase:** Known as the "spreading factor," this enzyme breaks down connective tissues at the bite site, allowing other healing substances to penetrate more effectively.
4. **Destabilase:** Possesses fibrin-dissolving and thrombolytic properties, preventing platelet aggregation.
5. **Bdellins:** Anti-inflammatory agents that inhibit enzymes like trypsin, plasmin, and acrosin.
6. **Tryptase Inhibitor:** Prevents proteolytic enzyme activity from the host's mast cells.
7. **Eglins:** Anti-inflammatory agents that inhibit enzymes such as alpha-chymotrypsin, chymase, and elastase.
8. **Carboxypeptidase A Inhibitors:** Increase blood flow at the bite site.
9. **Acetylcholine:** Acts as a vasodilator.

Probable Mode of Action of *Manjishtadi Kshara Basti*

Manjishtadi Kshara Basti is a potent *Niruha Basti* with particular indications for imbalances of *Vata* and *Rakta*. The herbs in the *Manjishtadi* group are particularly effective in conditions involving aggravated *Vata* and *Rakta*. *Kshara Basti* has properties that alleviate pain (*Shoolagna*) and cleanse the channels (*Srothoshodana*).

- *Manjishtha* has qualities that promote skin health (*Varnya*), balance blood disorders (*Raktadoshahara*), treat skin diseases (*Kushtahara*), and reduce swelling (*Shothahara*).
- *Guduchi* is known for its ability to purify the blood and alleviate pain (*Rakta Doshahara*, *Vedanasthapaka*).
- *Gomutra arka* cleanses the channels (*Sroto Shodhaka*) due to its hot potency (*Ushna Virya*), lightness (*Laghu*), dryness (*Ruksha*), sharpness (*Tikshnaguna*), pungent taste (*Katu rasa*), and post-digestive effect (*Katu Vipaka*).
- For *Anuvasana Basti*, *Ksheerbala Talla* was used. Its ingredients primarily possess heating properties, pacify *Vata* and *Kapha*, reduce swelling (*Shothahara*), relieve pain (*Vedana Sthapana*), and enhance digestion (*Deepana*). It also has scraping (*Lekhana*) and disease-fighting properties, particularly useful for treating conditions like varicose veins (*Siraja Granthi*).
- *Manjishtadi KsharaBasti* is particularly effective in balancing *Kapha* due to the presence of *Gomutra*, as well as *Pitta* and *Rakta* due to the *Manjishtadi Kwatha*, acting as a blood purifier (*Rakta prasadaka*) and balancing all three doshas (*Tridoshahara*).

Modern View and Probable Mode of Action of *Basti*

- In *Ayurvedic* treatment of *Vata* disorders, *Basti* is considered highly effective, even accounting for half of the treatment (*Ardachikithsa*). Although modern science may not fully recognize this practice, the probable modes of action include:
- Absorption mechanism: Even though the rectum is not a primary site for nutrient absorption, medications administered rectally can still be absorbed, producing both local and systemic effects.
- Neural stimulation: The administration of *Basti* may trigger neural responses.
- Chemical action: The ingredients in the *Basti* act chemically to achieve the desired effects.
- Mechanical action: The mechanical process of administering the *Basti* also plays a role.
- Water-soluble components are readily absorbed through the mucus membranes of the intestines, and short-chain fatty acids are absorbed in the colon under the influence of medication, facilitating the absorption of various substances.





Diet And Regimen

Diet and lifestyle play a critical role in enhancing the effects of treatments. The patient was advised to follow a regimen that would balance the *Pitta*, *Rakta*, and *Vata doshas*. They were instructed to avoid spicy, sour, oily, fermented, and refrigerated foods. The patient was also advised to avoid sun exposure, daytime naps, and staying up late at night.

CONCLUSION

This case highlights the successful integration of *Ayurvedic* principles in the management of venous ulcers. By combining local wound care with systemic treatment through oral medications and *Basti*, a comprehensive approach was achieved, promoting effective healing and reducing the risk of recurrence. The use of leech therapy (*Jalauka Avcharan*) provided additional benefits in improving blood circulation and reducing venous stasis, which are critical in managing chronic venous insufficiency. This holistic approach not only addresses the symptoms but also targets the underlying causes, demonstrating the potential of *Ayurvedic* protocols in managing complex chronic conditions like venous ulcers.

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Table.1:Basti schedule

16/05	17/05	18/05	19/05	20/05	21/05	22/05	23/05
A	N	N	N	N	N	N	A
	A	A	A	A	A	A	



Figure. 1: Treatment Protocol



Figure. 2: (Day 1st) Observation





Figure. 3: (Day 5th) Observation



Figure. 4: (Day 10th)



Figure. 5: Day 15th



Figure.6: Day 21st





Micro Vague Generalized Semi Closed Sets in Micro Vague Topological Spaces

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ABSTRACT

The principal point of this article is to address the new categories of sets in Micro Vague Topological Spaces. By applying fundamental definitions and results, the new sets namely Micro Vague Generalized Closed set, Micro Vague Generalized Semi Closed (Open) set, Micro Vague Generalized Pre-Closed (Open) Set, Micro Vague Generalized α Closed (Open) Set and Micro Vague Generalized Semi-Pre-Closed (Open) set in Micro Vague Topological Spaces are defined in this paper. Furthermore, some of the fundamental theorems, properties and the comparison between the existing sets are investigated with the suitable numerical examples.

Keywords: Micro Vague Generalized α Closed sets, Micro Vague Generalized α Open sets, Micro Vague Generalized Pre-Closed sets, Micro Vague Generalized Pre-Open sets, Micro Vague Generalized Semi-Pre-Closed sets, Micro Vague Generalized Semi-Pre-Open sets, Micro Vague Generalized Semi Closed sets, Micro Vague Generalized Semi Open sets.

INTRODUCTION

It is commonly known that topologists have developed a wide range of topologies. Fine topology, Supra topology, Ideal topology, Fuzzy topology, Nano topology and Micro topology are the topologies that exist today. Micro topology is an enlargement of nano topology, which has been established by S. Chandrasekar and it has maximum





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nine open sets and minimum four open sets. Fuzzy sets are established by Zadeh in 1965 in Mathematics. Each item in a Fuzzy set is given a single value in the range $[0,1]$, which reflects the degree of membership. Evidence supporting membership and evidence disproving membership cannot be separated under this single value. To affixing this, the concept of Vague sets was introduced by Gau and Buehrer [2] in 1993 which describes objects as having two distinct membership functions a true membership function and a false membership function. Vague sets are an extension of fuzzy sets. In the domain of fuzzy sets, this type of reasoning is also known as interval membership as opposed to point membership. In 1963, Levine [1] laid out semi-open sets and semi-closed sets. The elementary components of a topological space are closed sets. For instance, one may define the topology on a set using either the Kuratowski closure axioms or the axioms for closed sets. Levine [12] commenced the investigation of generalized closed sets in 1970. Since generalized closed sets are not only logical generalizations of closed sets, this idea has received a lot of topological attention in recent years. More crucially, they also propose a number of novel topological space features. S.P. Arya and T.Nour [16] introduced generalized semi closed sets in 1990. In 2021, Taha H. Jasim, Saja S. Mohsen, Kanayo S. Eke [24] introduced Micro generalized closed sets and Micro generalized continuity in Micro Topological Spaces. By combining Micro topological space and Vague topological space, Vargees Vahini T and Trinita Pricilla M [13] have introduced the new topological space called Micro Vague Topological Space. Now in this paper we present a new type of sets in the Micro Vague Topological Space named as Micro Vague Generalized α Closed sets, Micro Vague Generalized α Open sets, Micro Vague Generalized Pre-Closed sets, Micro Vague Generalized Pre-Open sets, Micro Vague Generalized Semi-Pre-Closed sets, Micro Vague Generalized Semi-Pre-Open sets, Micro Vague Generalized Semi Closed sets, Micro Vague Generalized Semi Open sets. Some of the basic definitions, theorems and universal characterizations are derived and investigated with the appropriate numerical examples.

PRELIMINARIES

Definition 2.1 [3]

A Vague set V in the universe of discourse X is characterized by a truth membership function t_v , and a falsity membership function f_v as follows:

$$t_v: X \rightarrow [0,1]; f_v: X \rightarrow [0,1] \text{ and } t_v + f_v \leq 1,$$

where $t_v(x)$ is a lower bound on the grade of membership of x derived from the evidence for x and $f_v(x)$ is a lower bound on the grade of membership of the negation of x derived from the evidence against x . The Vague set V is written as

$$V = \{(x, t_v(x), 1 - f_v(x)) | x \in X\}.$$

Definition 2.2 [5]

Let U be a non-empty finite set of objects called the universe and R be an equivalence relation on U named as the indiscernibility relation. Then U is divided into disjoint equivalence classes. Elements belonging to the same equivalence class are said to be indiscernible with one another. The pair (U, R) is said to be the approximation space. Let $X \subseteq U$.

- 1) The lower approximation of X with respect to R is the set of all objects, which can be for certain classified as X with respect to R and it is denoted by $L_R(X)$. That is,

$$L_R(X) = \bigcup_{x \in U} \{R(x) : R(x) \subseteq X\}$$
 where $R(x)$ denotes the equivalence class determined by $x \in U$.
- 2) The upper approximation of X with respect to R is the set of all objects, which can be possibly classified as X with respect to R and it is denoted by $U_R(X)$. That is,

$$U_R(X) = \bigcup_{x \in U} \{R(x) : R(x) \cap X \neq \emptyset\}$$

- 3) The boundary region of X with respect to R is the set of all objects, which can be classified neither as X nor as $B_R(X)$ denotes not- X with respect to R and it. That is,

$$B_R(X) = U_R(X) - L_R(X).$$





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Definition 2.3 [2]

Let U be a universe, R be an equivalence relation on U and $\tau_R(X) = \{U, \phi, L_R(X), U_R(X), B_R(X)\}$ where $X \subseteq U$ satisfies the following axioms

1. $U, \phi \in \tau_R(X)$
2. The union of the elements of any sub-collection of $\tau_R(X)$ is in $\tau_R(X)$
3. The intersection of the elements of any finite sub collection of $\tau_R(X)$ is in $\tau_R(X)$.

Then $\tau_R(X)$ is called the Nano topology on U with respect to X . The space $(U, \tau_R(X))$ is the Nano topological space. The elements of $\tau_R(X)$ are called Nano open sets.

Definition 2.4 [4]

$(U, \tau_R(X))$ is a Nano topological space here $\mu_R(X) = \{N \cup (N' \cap \mu) : N, N' \in \tau_R(X)\}$ and is called Micro topology of $\tau_R(X)$ by μ where $\mu \notin \tau_R(X)$. The Micro topology $\mu_R(X)$ satisfies the following axioms

- (1) $U, \phi \in \mu_R(X)$.
- (2) The union of the elements of any sub-collection of $\mu_R(X)$ is in $\mu_R(X)$.
- (3) The intersection of the elements of any finite sub collection of $\mu_R(X)$ is in $\mu_R(X)$.

Then $\mu_R(X)$ is called the Micro topology on U with respect to X . The triplet $(U, \tau_R(X), \mu_R(X))$ is called Micro topological spaces and the elements of $\mu_R(X)$ are called Micro open sets and the complement of a Micro open set is called a Micro closed set.

Definition 2.5 [4]

- $Mic - int(A) = \cup \{G / G \text{ is a Mic - OS in } X \text{ and } G \subseteq A\}$.
- $Mic - cl(A) = \cap \{K / K \text{ is a Mic - CS in } X \text{ and } A \subseteq K\}$.

Definition 2.6

Let (X, τ) be a topological Space. A subset A of X is called:

- 1) Semi Closed set [1] if $int(cl(A)) \subseteq A$.
- 2) Semi Open set [1] if $A \subseteq int(cl(A))$.
- 3) Pre-Closed set [17] if $A \subseteq cl(int(A))$.
- 4) Pre-Open set [17] if $cl(int(A)) \subseteq A$.
- 5) Regular Closed set [20] if $A = cl(int(A))$.
- 6) Regular Open set [20] if $int(cl(A)) = A$.
- 7) α Closed set [19] if $cl(int(cl(A))) \subseteq A$.
- 8) α Open set [19] if $A \subseteq int(cl(int(A)))$.
- 9) Semi-Pre-Closed set [18] if $int(cl(int(A))) \subseteq A$.
- 10) Semi-Pre-Open set [18] if $A \subseteq cl(int(cl(A)))$.

Definition 2.7

Let (X, τ) be a topological Space. A subset A of X is called:

- 1) Generalized Closed set [12] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is Open in X .
- 2) Generalized Semi Closed set [16] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X .
- 3) Generalized Pre-Closed set [22] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X .
- 4) Generalized α Closed set [21] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is α open in X .
- 5) α Generalized Closed set [21] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X .
- 6) Generalized Semi-Pre-Closed set [23] if $spcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X .

Definition 2.8 [13]

Let $(U, \tau_R(A))$ be a Nano Vague Topological Space. Let $\eta_R(A) = \{S \cup (S' \cap \eta) : S, S' \in \tau_R(A) \text{ and } \eta \notin \tau_R(A)\}$. Then $\eta_R(A)$ is called the Micro Vague Topology of $\tau_R(A)$ by η on U with respect to A . The triplet $(U, \tau_R(A), \eta_R(A))$ is called the Micro Vague Topological Space. The elements of $\eta_R(A)$ are called Micro Vague open sets and the complement of a Micro Vague Open set is called a Micro Vague Closed set.





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Definition 2.9 [13]

Let U be the Universe and $X \subseteq U$. Let \mathcal{G} and \mathcal{H} be two \mathcal{MV} sets in the \mathcal{MV} Topological Space $(U, \tau_R(X), \eta_R(X))$ of the form $\mathcal{G} = \{ \langle x, [\mu_{\mathcal{G}}(x), \gamma_{\mathcal{G}}(x)] \rangle / x \in X \}$ and $\mathcal{H} = \{ \langle x, [\mu_{\mathcal{H}}(x), \gamma_{\mathcal{H}}(x)] \rangle / x \in X \}$ respectively. Then the following conditions holds:

- (i) $\mathcal{G} \subseteq \mathcal{H}$ iff $\mu_{\mathcal{G}}(x) \leq \mu_{\mathcal{H}}(x), \gamma_{\mathcal{G}}(x) \leq \gamma_{\mathcal{H}}(x) \forall x \in U$
- (ii) $\mathcal{G} = \mathcal{H}$ iff $\mathcal{G} \subseteq \mathcal{H}$ and $\mathcal{H} \subseteq \mathcal{G}$
- (iii) $\mathcal{G}^c = \{ \langle x, 1 - \gamma_{\mathcal{G}}(x), 1 - \mu_{\mathcal{G}}(x) \rangle / \forall x \in U \}$
- (iv) $\mathcal{G} \cup \mathcal{H} = \{ \langle x, (\mu_{\mathcal{G}}(x) \vee \mu_{\mathcal{H}}(x), \gamma_{\mathcal{G}}(x) \vee \gamma_{\mathcal{H}}(x)) \rangle / \forall x \in U \}$
- (v) $\mathcal{G} \cap \mathcal{H} = \{ \langle x, (\mu_{\mathcal{G}}(x) \wedge \mu_{\mathcal{H}}(x), \gamma_{\mathcal{G}}(x) \wedge \gamma_{\mathcal{H}}(x)) \rangle / \forall x \in U \}$
- (vi) $0_{\mathcal{MV}} = \langle x, (0,0) \rangle$ and $1_{\mathcal{MV}} = \langle x, (1,1) \rangle \forall x \in U$

Definition 2.10 [13]

Let $(U, \tau_R(X), \eta_R(X))$ be a \mathcal{MV} Topological Space and $\mathcal{Q} \subseteq U$. Then, \mathcal{Q} is said to be \mathcal{MV} Pre-Open if $\mathcal{Q} \subseteq \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{Q}))$ and \mathcal{MV} Pre closed if $\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(\mathcal{Q})) \subseteq \mathcal{Q}$.

Definition 2.11 [13]

Let $(U, \tau_R(X), \eta_R(X))$ be a \mathcal{MV} Topological Space and $\mathcal{P} \subseteq U$. Then, \mathcal{P} is said to be \mathcal{MV} -Semi Open if $\mathcal{P} \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(\mathcal{P}))$ and \mathcal{MV} -Semi Closed if $\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{P})) \subseteq \mathcal{P}$.

Various Types of Closed sets in Micro Vague Topological Space

Definition 3.1

A \mathcal{MV} Set A in the Micro Vague Topological Space $(U, \mathcal{V}_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is called as the Micro Vague α Closed set if $\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A))) \subseteq A$ and Micro Vague α Open if $A \subseteq \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))$.

Definition 3.2

Let A be a \mathcal{MV} set of the \mathcal{MV} Topological space $(U, \mathcal{V}_R(\mathcal{S}), \eta_R(\mathcal{S}))$. The Micro Vague α interior of A ($\mathcal{MV} - \alpha - \text{int}(A)$) and Micro Vague α closure of A ($\mathcal{MV} - \alpha - \text{cl}(A)$) are defined as:

1. $\mathcal{MV} - \alpha - \text{int}(A) = \bigcup \{ H / H \text{ is a } \mathcal{MV}\alpha\mathcal{OS} \text{ in } U \text{ and } H \subseteq A \}$
2. $\mathcal{MV} - \alpha - \text{cl}(A) = \bigcap \{ T / T \text{ is a } \mathcal{MV}\alpha\mathcal{CS} \text{ in } U \text{ and } A \subseteq T \}$.

Remark 3.3

- (i) $\mathcal{MV} - \alpha - \text{int}(A) = A \cap \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))$
- (ii) $\mathcal{MV} - \alpha - \text{cl}(A) = A \cup \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A)))$

Definition3.4

A \mathcal{MV} Set A in the Micro Vague Topological Space $(U, \mathcal{V}_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is called as the Micro Vague Semi-Pre Closed set if $\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))) \subseteq A$ and Micro Vague Semi-Pre Open if $A \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A)))$.

Definition 3.5

Let A be a \mathcal{MV} set of the \mathcal{MV} Topological space $(U, \mathcal{V}_R(\mathcal{S}), \eta_R(\mathcal{S}))$. The Micro Vague Semi-Pre interior of A ($\mathcal{MV} - \text{sp} - \text{int}(A)$) and Micro Vague Semi-Pre closure of A ($\mathcal{MV} - \text{sp} - \text{cl}(A)$) are defined as:

1. $\mathcal{MV} - \text{sp} - \text{int}(A) = \bigcup \{ H / H \text{ is a } \mathcal{MVSP}\mathcal{OS} \text{ in } U \text{ and } H \subseteq A \}$
2. $\mathcal{MV} - \text{sp} - \text{cl}(A) = \bigcap \{ T / T \text{ is a } \mathcal{MVSP}\mathcal{CS} \text{ in } U \text{ and } A \subseteq T \}$.

Remark 3.6

- (i) $\mathcal{MV} - \text{sp} - \text{int}(A) = A \cap \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A)))$





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$$(ii) \mathcal{MV} - sp - cl(A) = A \cup \mathcal{MV} - \text{int}(\mathcal{MV} - cl(\mathcal{MV} - \text{int}(A)))$$

Definition 3.7

A \mathcal{MV} Set A in the Micro Vague Topological Space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$ is called as the Micro Vague Regular Closed set if $A = \mathcal{MV} - cl(\mathcal{MV} - \text{int}(A))$ and Micro Vague Regular Open if $\mathcal{MV} - \text{int}(\mathcal{MV} - cl(A)) = A$.

Definition 3.8

Let A be a \mathcal{MV} set of the \mathcal{MV} Topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$. The Micro Vague-Regular- interior of A ($\mathcal{MV} - r - \text{int}(A)$) and Micro Vague Regular closure of A ($\mathcal{MV} - r - cl(A)$) are defined as:

1. $\mathcal{MV} - r - \text{int}(A) = \bigcup \{H/H \text{ is a } \mathcal{MVROS} \text{ in } U \text{ and } H \subseteq A\}$
2. $\mathcal{MV} - r - cl(A) = \bigcap \{T/T \text{ is a } \mathcal{MVRCs} \text{ in } U \text{ and } A \subseteq T\}$.

Definition 3.9

A \mathcal{MV} set A is said to be Micro Vague Generalized closed set (\mathcal{MVGCs}) in the topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$, if $\mathcal{MV} - cl(A) \subseteq \mathcal{U}$ whenever $A \subseteq \mathcal{U}$ AND \mathcal{U} is \mathcal{MV} -OPEN IN U . THE COMPLEMENT OF THE \mathcal{MVGCs} IS CALLED AS THE

MICRO VAGUE GENERALIZED OPEN SET IN $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$.

Definition 3.10

Let A be a \mathcal{MV} set of the \mathcal{MV} Topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$. The Micro Vague Pre interior of A ($\mathcal{MV} - p - \text{int}(A)$) and Micro Vague Pre closure of A ($\mathcal{MV} - p - cl(A)$) are defined as:

1. $\mathcal{MV} - p - \text{int}(A) = \bigcup \{H/H \text{ is a } \mathcal{MVPOS} \text{ in } U \text{ and } H \subseteq A\}$
2. $\mathcal{MV} - p - cl(A) = \bigcap \{T/T \text{ is a } \mathcal{MVPCS} \text{ in } U \text{ and } A \subseteq T\}$.

Remark 3.11

- (i) $\mathcal{MV} - p - \text{int}(A) = A \cap (\mathcal{MV} - \text{int}(\mathcal{MV} - cl(A)))$
- (ii) $\mathcal{MV} - p - cl(A) = A \cup (\mathcal{MV} - cl(\mathcal{MV} - \text{int}(A)))$

Definition 3.12

A \mathcal{MV} set A is said to be Micro Vague Generalized Pre closed set (\mathcal{MVGPCs}) in the topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$, if $\mathcal{MV} - pcl(A) \subseteq \mathcal{U}$ whenever $A \subseteq \mathcal{U}$ AND \mathcal{U} is \mathcal{MV} -OPEN IN U . THE COMPLEMENT OF THE \mathcal{MVGPCs}

IS CALLED AS THE MICRO VAGUE GENERALIZED PRE-OPEN SET IN $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$.

Definition 3.13

A \mathcal{MV} set A is said to be Micro Vague Generalized α closed set ($\mathcal{MVG\alpha Cs}$) in the topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$, if $\mathcal{MV} - acl(A) \subseteq \mathcal{U}$ whenever $A \subseteq \mathcal{U}$ AND \mathcal{U} is \mathcal{MV} - α -OPEN IN U . THE COMPLEMENT OF THE $\mathcal{MVG\alpha Cs}$ IS CALLED AS THE **MICRO VAGUE GENERALIZED α OPEN SET IN $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$.**

Definition 3.14

A \mathcal{MV} set A is said to be Micro Vague α Generalized closed set ($\mathcal{MV\alpha GCs}$) in the topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$, if $\mathcal{MV} - acl(A) \subseteq \mathcal{U}$ whenever $A \subseteq \mathcal{U}$ AND \mathcal{U} is \mathcal{MV} -OPEN IN U . THE COMPLEMENT OF THE $\mathcal{MV\alpha GCs}$ IS CALLED AS THE

MICRO VAGUE α GENERALIZED OPEN SET IN $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$.

Definition 3.15

A \mathcal{MV} set A is said to be Micro Vague Generalized Semi-Pre closed set ($\mathcal{MVGSPCS}$) in the topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$, if $\mathcal{MV} - sp - cl(A) \subseteq \mathcal{U}$ whenever $A \subseteq \mathcal{U}$ AND \mathcal{U} is \mathcal{MV} -OPEN IN U . THE COMPLEMENT OF THE $\mathcal{MVGSPCS}$ IS CALLED AS THE **MICRO VAGUE GENERALIZED SEMI-PRE-OPEN SET IN $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$.**





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Micro Vague Generalized Semi Closed sets

Definition 4.1

Let A be a \mathcal{MV} set of the \mathcal{MV} Topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$. The Micro Vague Semi interior of A ($\mathcal{MV} - s - \text{int}(A)$) and Micro Vague Semi closure of A ($\mathcal{MV} - s - \text{cl}(A)$) are defined as:

1. $\mathcal{MV} - s - \text{int}(A) = \bigcup \{H/H \text{ is a } \mathcal{MV}\mathcal{SOS} \text{ in } U \text{ and } H \subseteq A\}$
2. $\mathcal{MV} - s - \text{cl}(A) = \bigcap \{T/T \text{ is a } \mathcal{MV}\mathcal{SCS} \text{ in } U \text{ and } A \subseteq T\}$.

Remark 4.2

- (i) $\mathcal{MV} - s - \text{int}(A) = A \cap (\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))$
- (ii) $\mathcal{MV} - s - \text{cl}(A) = A \cup (\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A)))$

Definition 4.3

A \mathcal{MV} set A is said to be Micro Vague Generalized Semi closed set ($\mathcal{MV}\mathcal{GSCS}$) in the topological space $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$, if $\mathcal{MV} - \text{scl}(A) \subseteq \mathcal{U}$ whenever $A \subseteq \mathcal{U}$ and \mathcal{U} is \mathcal{MV} -OPEN IN \mathcal{U} . THE FAMILY OF ALL $\mathcal{MV}\mathcal{GSCS}$ IN THE \mathcal{MV} -TOPOLOGICAL SPACE $(\mathcal{U}, \vartheta_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$ is denoted by $\mathcal{MV}\mathcal{GSC}(\mathcal{S})$.

Example 4.4

Let $\mathcal{U} = \{\rho, \lambda, \theta\}$ BE THE UNIVERSE OF DISCOURSE. $\mathcal{U}/\mathcal{R} = \{\{\rho, \lambda\}, \{\theta\}\}$ BE THE EQUIVALENCE RELATION ON \mathcal{U} . LET $\mathcal{S} = \{< \rho, (0.5, 0.7) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ BE A SUBSET OF \mathcal{U} . THEN, $\vartheta_{\mathcal{R}}(\mathcal{S}) = \{0_{\mathcal{NV}}, 1_{\mathcal{NV}}, \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.7) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.7) >, < \theta, (0.2, 0.3) >\}$ is a Nano Vague Topology on \mathcal{U} . Let $\eta = \{< \rho, (0.3, 0.4) >, < \lambda, (0.1, 0.9) >, < \theta, (0.2, 0.6) >\}$. Then, $\eta_{\mathcal{R}}(A) = \{0_{\mathcal{MV}}, 1_{\mathcal{MV}}, \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.7) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.7) >, < \theta, (0.2, 0.3) >\}, \{< \rho, (0.3, 0.4) >, < \lambda, (0.1, 0.9) >, < \theta, (0.2, 0.6) >\}, \{< \rho, (0.2, 0.4) >, < \lambda, (0.1, 0.4) >, < \theta, (0.2, 0.6) >\}, \{< \rho, (0.3, 0.4) >, < \lambda, (0.1, 0.7) >, < \theta, (0.2, 0.6) >\}, \{< \rho, (0.3, 0.4) >, < \lambda, (0.1, 0.7) >, < \theta, (0.2, 0.3) >\}, \{< \rho, (0.3, 0.4) >, < \lambda, (0.2, 0.9) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.3, 0.4) >, < \lambda, (0.2, 0.7) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.9) >, < \theta, (0.7, 0.8) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.9) >, < \theta, (0.2, 0.6) >\}, \{< \rho, (0.5, 0.7) >, < \lambda, (0.5, 0.7) >, < \theta, (0.2, 0.6) >\}$ is a Micro Vague Topology on \mathcal{U} with respect to \mathcal{S} and the elements in the Micro Vague Topology are called Micro Vague Open sets. The triplet $(\mathcal{U}, \tau_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$ is called as the Micro Vague Topological Space.

Example 4.5

Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{MV}\mathcal{GSCS}$ in \mathcal{U} .

Theorem 4.6

Every Micro Vague Closed set is Micro Vague Generalized Semi Closed set.

Proof: Let \mathcal{K} be \mathcal{MV} -Closed Set in $(\mathcal{U}, \tau_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$ and let $\mathcal{K} \subseteq \mathcal{V}$, where \mathcal{V} is an \mathcal{MV} -Open set in \mathcal{U} . Since \mathcal{K} is \mathcal{MV} -closed, then $\mathcal{MV} - \text{cl}(\mathcal{K}) = \mathcal{K}$. Therefore $\mathcal{MV} - \text{cl}(\mathcal{K}) = \mathcal{K}$ and $\mathcal{K} \subseteq \mathcal{V}$, implies that $\mathcal{MV} - \text{cl}(\mathcal{K}) \subseteq \mathcal{V}$. Also, $\mathcal{MV} - \text{scl}(\mathcal{K}) \subseteq \mathcal{MV} - \text{cl}(\mathcal{K})$ implies $\mathcal{MV} - \text{scl}(\mathcal{K}) \subseteq \mathcal{V}$ where $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is \mathcal{MV} -Open set in \mathcal{U} . Therefore, is a $\mathcal{MV}\mathcal{GSCS}$.

Remark 4.7

The converse of the above theorem need not to be true. It is shown in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_{\mathcal{R}}(\mathcal{S}), \eta_{\mathcal{R}}(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{MV}\mathcal{GSCS}$ in \mathcal{U} but not \mathcal{MVCS} in \mathcal{U} .

Theorem 4.8

Every Micro Vague Generalized Closed set is Micro Vague Generalized Semi closed set.





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Proof: Let \mathcal{K} be Micro Vague Generalized Closed set. Then $\mathcal{M}\mathcal{V} - cl(A) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is Micro Vague Open in U . We know that $\mathcal{M}\mathcal{V} - scl(\mathcal{K}) \subseteq \mathcal{M}\mathcal{V} - cl(\mathcal{K})$; Therefore $\mathcal{M}\mathcal{V} - scl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is Micro Vague Open in U . Hence \mathcal{K} is $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U .

Remark 4.9

The converse of the above theorem need not to be true. It is shown in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the $\mathcal{M}\mathcal{V}$ Set $\mathcal{K} = \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U but not $\mathcal{M}\mathcal{V}\mathcal{SCS}$ in U .

Theorem 4.10

Every Micro Vague Semi closed set is Micro Vague Generalized Semi Closed set.

Proof: Let \mathcal{K} be $\mathcal{M}\mathcal{VSCS}$ in U and let $\mathcal{K} \subseteq \mathcal{V}$ where \mathcal{V} is $\mathcal{M}\mathcal{V}$ open in U . Since \mathcal{K} is $\mathcal{M}\mathcal{VSCS}$, we have $\mathcal{M}\mathcal{V} - int(\mathcal{M}\mathcal{V} - cl(\mathcal{K})) \subseteq \mathcal{K}$. This implies that $\mathcal{M}\mathcal{V} - scl(\mathcal{K}) = \mathcal{K} \cup \mathcal{M}\mathcal{V} - int(\mathcal{M}\mathcal{V} - cl(\mathcal{K})) \subseteq \mathcal{K}$ and $\mathcal{K} \subseteq \mathcal{V}$. This results that $\mathcal{M}\mathcal{V} - scl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is $\mathcal{M}\mathcal{V}$ -open in U . Hence \mathcal{K} is $\mathcal{M}\mathcal{V}\mathcal{GSCS}$.

Remark 4.11

The converse of the above theorem need not to be true. It is shown in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the $\mathcal{M}\mathcal{V}$ set $\mathcal{K} = \{< \rho, (0.3, 0.4) >, < \lambda, (0.6, 0.7) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U but not $\mathcal{M}\mathcal{VSCS}$ in U .

Theorem 4.12

Every Micro Vague α closed set is Micro Vague Generalized Semi closed set.

Proof: Let \mathcal{K} be $\mathcal{M}\mathcal{V}\alpha\mathcal{CS}$ in U and let $\mathcal{K} \subseteq \mathcal{V}$ where \mathcal{V} is $\mathcal{M}\mathcal{V}$ open set in U . Since \mathcal{K} is a $\mathcal{M}\mathcal{V}\alpha\mathcal{CS}$, we have $\mathcal{M}\mathcal{V} - cl(\mathcal{M}\mathcal{V} - int(\mathcal{M}\mathcal{V} - cl(\mathcal{K}))) \subseteq \mathcal{K}$. We know that $\mathcal{K} \subseteq \mathcal{M}\mathcal{V} - cl(\mathcal{K})$; this implies that $\mathcal{M}\mathcal{V} - int(\mathcal{M}\mathcal{V} - cl(\mathcal{K})) \subseteq \mathcal{M}\mathcal{V} - cl(\mathcal{M}\mathcal{V} - int(\mathcal{M}\mathcal{V} - cl(\mathcal{K})))$. Therefore $\mathcal{M}\mathcal{V} - int(\mathcal{M}\mathcal{V} - cl(\mathcal{K})) \subseteq \mathcal{K}$ (i.e) $\mathcal{M}\mathcal{V} - scl(\mathcal{K}) \subseteq \mathcal{K}$ and $\mathcal{K} \subseteq \mathcal{V}$ implies that $\mathcal{M}\mathcal{V} - scl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is $\mathcal{M}\mathcal{V}$ -open in U . Hence \mathcal{K} is a $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U .

Remark 4.13

The converse of the above theorem need not to be true which can be shown in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the $\mathcal{M}\mathcal{V}$ Set $\mathcal{K} = \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U but not $\mathcal{M}\mathcal{V}\alpha\mathcal{CS}$ in U .

Theorem 4.14

Every Micro Vague Regular Closed set is Micro Vague Generalized Semi closed set.

Proof: Let \mathcal{K} be $\mathcal{M}\mathcal{V}\mathcal{RCS}$ in U that is $\mathcal{K} = \mathcal{M}\mathcal{V} - cl(\mathcal{M}\mathcal{V} - int(\mathcal{K}))$. This implies that $\mathcal{M}\mathcal{V} - cl(\mathcal{K}) = \mathcal{M}\mathcal{V} - cl(\mathcal{M}\mathcal{V} - cl(\mathcal{M}\mathcal{V} - int(\mathcal{K})))$ which results as $\mathcal{M}\mathcal{V} - cl(\mathcal{K}) = \mathcal{M}\mathcal{V} - cl(\mathcal{M}\mathcal{V} - int(\mathcal{K})) = \mathcal{K}$. Since, $\mathcal{M}\mathcal{V} - cl(\mathcal{K}) = \mathcal{K}$, we conclude that \mathcal{K} is $\mathcal{M}\mathcal{VCS}$ in U . By theorem 4.6, \mathcal{K} is a $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U .

Remark 4.15

The converse of the above theorem need not to be true which has been shown in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the $\mathcal{M}\mathcal{V}$ Set $\mathcal{K} = \{< \rho, (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{M}\mathcal{V}\mathcal{GSCS}$ in U but not $\mathcal{M}\mathcal{V}\mathcal{RCS}$ in U .

Theorem 4.16

Every Micro Vague Generalized α Closed Set is Micro Vague Generalized Semi Closed Set.





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Proof: Let \mathcal{K} be $\mathcal{MV}\alpha\mathcal{CS}$ in U and let $\mathcal{K} \subseteq \mathcal{V}$ where \mathcal{V} is $\mathcal{MV}\alpha$ -open set in U . Since \mathcal{K} is a $\mathcal{MV}\alpha\mathcal{CS}$, we have $\mathcal{MV} - \alpha cl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is $\mathcal{MV}\alpha\mathcal{OS}$ in U . This implies that $\mathcal{MV} - \alpha cl(\mathcal{K}) = \mathcal{K} \cup \mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K}))) \subseteq \mathcal{V}$. We know that $\mathcal{K} \subseteq \mathcal{MV} - cl(\mathcal{K})$; this implies that $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K}))) \subseteq \mathcal{V}$. (i.e) $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{MV} - \alpha cl(\mathcal{K}) \subseteq \mathcal{V}$ implies that $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is $\mathcal{MV}\mathcal{OS}$ in U . Hence \mathcal{K} is a $\mathcal{MV}\mathcal{GSCS}$ in U .

Remark 4.17

The converse of the above theorem need not to be true which can be shown in the following example. Let us consider the Micro Vague Topological Space $(\mathbf{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{MV}\mathcal{GSCS}$ in U but not $\mathcal{MV}\alpha\mathcal{CS}$ in U .

Theorem 4.18

Every Micro Vague α Generalized Closed Set is Micro Vague Generalized Semi Closed Set.

Proof: Let \mathcal{K} be $\mathcal{MV}\alpha\mathcal{GCS}$ in U and let $\mathcal{K} \subseteq \mathcal{V}$ where \mathcal{V} is \mathcal{MV} -open set in U . Since \mathcal{K} is a $\mathcal{MV}\alpha\mathcal{GCS}$, we have $\mathcal{MV} - \alpha cl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is $\mathcal{MV}\mathcal{OS}$ in U . This implies that $\mathcal{MV} - \alpha cl(\mathcal{K}) = \mathcal{K} \cup \mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K}))) \subseteq \mathcal{V}$. We know that $\mathcal{K} \subseteq \mathcal{MV} - cl(\mathcal{K})$; this implies that $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K}))) \subseteq \mathcal{V}$. (i.e) $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{MV} - \alpha cl(\mathcal{K}) \subseteq \mathcal{V}$ implies that $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{V}$ whenever $\mathcal{K} \subseteq \mathcal{V}$ and \mathcal{V} is $\mathcal{MV}\mathcal{OS}$ in U . Hence \mathcal{K} is a $\mathcal{MV}\mathcal{GSCS}$ in U .

Remark 4.19

The converse of the above theorem need not to be true which can be shown in the following example. Let us consider the Micro Vague Topological Space $(\mathbf{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.2, 0.4) >, < \lambda, (0.2, 0.4) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{MV}\mathcal{GSCS}$ in U but not $\mathcal{MV}\alpha\mathcal{GCS}$ in U .

Theorem 4.20

Every Micro Vague Semi Closed set is Micro Vague Semi-Pre-Closed set

Proof: Let \mathcal{K} be \mathcal{MVSCS} in U . By hypothesis, we have $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{K}$. Since $\mathcal{MV} - int(\mathcal{K}) \subseteq \mathcal{K}$, we get $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}))) \subseteq \mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{K}$. This implies that \mathcal{K} is a \mathcal{MVSPCS} .

Remark 4.21

The converse of the above theorem need not to be true which is seen from the following example. Let us consider the Micro Vague Topological Space $(\mathbf{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.3, 0.6) >, < \lambda, (0.1, 0.5) >, < \theta, (0.2, 0.3) >\}$ is a \mathcal{MVSPCS} in U but not \mathcal{MVSCS} in U .

Theorem 4.22

Every Micro Generalized Semi Closed set is Micro Vague Semi-Pre-closed set

Proof: Let \mathcal{K} be \mathcal{MVGSCS} in U such that $\mathcal{K} \subseteq U$ and U is a $\mathcal{MV}\mathcal{OS}$. Since \mathcal{K} is a \mathcal{MVGSCS} , we have $\mathcal{MV} - scl(\mathcal{K}) \subseteq U$. (i.e) $\mathcal{K} \cup [\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K}))] \subseteq U$ which results that $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq U$. Since $\mathcal{MV} - int(\mathcal{K}) \subseteq \mathcal{K}$, we get $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}))) \subseteq \mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq U$. This implies that \mathcal{K} is a \mathcal{MVSPCS} .

Remark 4.23

The converse of the above theorem need not to be true which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathbf{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.5, 0.7) >, < \lambda, (0.1, 0.3) >, < \theta, (0.7, 0.8) >\}$ is a \mathcal{MVSPCS} in U but not \mathcal{MVGSCS} in U .





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Theorem 4.24

Every Micro Generalized Semi Closed set is Micro Vague Generalized Semi-Pre-Closed set.

Proof: Let \mathcal{K} be \mathcal{MVGSCS} in U such that $\mathcal{MV} - scl(\mathcal{K}) \subseteq U$ whenever $\mathcal{K} \subseteq U$ and U is \mathcal{MVO} . This implies that $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq U$ whenever $\mathcal{K} \subseteq U$ and U is \mathcal{MVO} . Since $\mathcal{MV} - int(\mathcal{K}) \subseteq \mathcal{K}$, we get $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}))) \subseteq \mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq U$. This results that $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}))) \subseteq U$. Since $\mathcal{K} \subseteq U$ and $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}))) \subseteq U$, we have $\mathcal{K} \cup \mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}))) \subseteq U$ (i.e) $\mathcal{MV} - spcl(\mathcal{K}) \subseteq U$. Therefore, $\mathcal{MV} - spcl(\mathcal{K}) \subseteq U$ whenever $\mathcal{K} \subseteq U$ where U is \mathcal{MVO} . Hence \mathcal{K} is a $\mathcal{MVGSPCS}$ in U .

Remark 4.25

The converse of the above theorem need not to be true which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MVSet} $\mathcal{K} = \{< \rho (0.5, 0.7) >, < \lambda, (0.1, 0.3) >, < \theta, (0.7, 0.8) >\}$ is a $\mathcal{MVGSPCS}$ in U but not \mathcal{MVGSCS} in U .

Remark 4.26

From the above theorems and examples, we have the following diagrammatic representation.

Theorem 4.27

If \mathcal{K} and \mathcal{L} are Micro Vague Generalized Semi closed sets, then $\mathcal{K} \cap \mathcal{L}$ is also a Micro Vague Generalized Semi closed set.

Proof: Let \mathcal{K} and \mathcal{L} be two \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Then $\mathcal{K} \subseteq U$ and $\mathcal{L} \subseteq U$ implies that $\mathcal{K} \cap \mathcal{L} \subseteq U$. Since \mathcal{K} and \mathcal{L} are \mathcal{MVGSCS} , $\mathcal{MV} - scl(\mathcal{K}) \subseteq U$ and $\mathcal{MV} - scl(\mathcal{L}) \subseteq U$. Hence $\mathcal{MV} - scl(\mathcal{K}) \cap \mathcal{MV} - scl(\mathcal{L}) \subseteq U$. This implies that $\mathcal{MV} - scl(\mathcal{K} \cap \mathcal{L}) \subseteq U$. Therefore $\mathcal{MV} - scl(\mathcal{K} \cap \mathcal{L}) \subseteq U$ whenever $\mathcal{K} \cap \mathcal{L} \subseteq U$ and U is Micro Vague Open. Thus $\mathcal{K} \cap \mathcal{L}$ is \mathcal{MVGSCS} .

Example 4.28: Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Let $\mathcal{K} = \{< \rho (0.3, 0.4) >, < \lambda, (0.2, 0.9) >, < \theta, (0.7, 0.8) >\}$ and $\mathcal{L} = \{< \rho (0.3, 0.4) >, < \lambda, (0.3, 0.5) >, < \theta, (0.7, 0.8) >\}$ be \mathcal{MVGSCS} in U . Then Since $\mathcal{MV} - scl(\mathcal{K} \cap \mathcal{L}) \subseteq U$ whenever $\mathcal{K} \cap \mathcal{L} \subseteq U$ and U is \mathcal{MV} -Open set in U , $\mathcal{K} \cap \mathcal{L}$ is also a \mathcal{MVGSCS} in U .

Remark 4.29

The Union of any two Micro Vague Generalized Semi Closed sets need not to be a Micro Vague Generalized semi closed set. This can be seen in the following example.

Example 4.30: Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Let $\mathcal{K} = \{< \rho (0.3, 0.4) >, < \lambda, (0.2, 0.9) >, < \theta, (0.7, 0.8) >\}$ and $\mathcal{L} = \{< \rho (0.5, 0.7) >, < \lambda, (0.5, 0.9) >, < \theta, (0.2, 0.6) >\}$ be \mathcal{MVGSCS} in U . But the Union $\mathcal{K} \cup \mathcal{L}$ is not a \mathcal{MVGSCS} since $\mathcal{MV} - scl(\mathcal{K} \cup \mathcal{L}) \not\subseteq \mathcal{K} \cup \mathcal{L}$.

Theorem 4.31

If \mathcal{K} is a Micro Vague Generalized semi closed sets in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and $\mathcal{K} \subseteq \mathcal{L} \subseteq \mathcal{MV} - scl(\mathcal{K})$, then \mathcal{L} is a Micro Vague Generalized semi closed set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let U be a \mathcal{MVO} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$, such that $\mathcal{L} \subseteq U$. Since $\mathcal{K} \subseteq \mathcal{L} \subseteq U$, we have $\mathcal{K} \subseteq U$. Again, since \mathcal{K} is a \mathcal{MVGSCS} , $\mathcal{MV} - scl(\mathcal{K}) \subseteq U$. By hypothesis, $\mathcal{L} \subseteq \mathcal{MV} - scl(\mathcal{K})$. W.K.T, $\mathcal{MV} - scl(\mathcal{L}) \subseteq \mathcal{MV} - scl(\mathcal{MV} - scl(\mathcal{K})) = \mathcal{MV} - scl(\mathcal{K})$. That is $\mathcal{MV} - scl(\mathcal{L}) \subseteq \mathcal{MV} - scl(\mathcal{K})$. This implies that $\mathcal{MV} - scl(\mathcal{L}) \subseteq U$. Hence \mathcal{L} is a \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.





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Example 4.32: Let \mathcal{K} be a \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and $\mathcal{K} = \{ \langle \rho, (0.1, 0.4) \rangle, \langle \lambda, (0.1, 0.4) \rangle, \langle \theta, (0.2, 0.6) \rangle \} \subseteq \mathcal{L} = \{ \langle \rho, (0.2, 0.4) \rangle, \langle \lambda, (0.1, 0.4) \rangle, \langle \theta, (0.2, 0.6) \rangle \}$. Since $\mathcal{K} \subseteq \mathcal{L} \subseteq \mathcal{MV} - scl(\mathcal{K})$, \mathcal{L} is also a \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Theorem 4.33

A Micro Vague set \mathcal{K} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is a Micro Vague Generalized Semi Closed set if and only if $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{L}$ where \mathcal{L} is a Micro Vague Open set and $\mathcal{K} \subseteq \mathcal{L}$.

Proof: Assume that \mathcal{K} is a \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Let \mathcal{L} be a \mathcal{MV} -Open set in U such that $\mathcal{K} \subseteq \mathcal{L}$. Then \mathcal{L}^c is a \mathcal{MV} -Closed set in U , such that $\mathcal{L}^c \subseteq \mathcal{K}^c$. Since \mathcal{K}^c is a \mathcal{MVGSO} , $\mathcal{L}^c \subseteq \mathcal{MV} - s - int(\mathcal{K}^c)$. Since, $\mathcal{MV} - s - int(\mathcal{K}^c) = [\mathcal{MV} - scl(\mathcal{K})]^c$. Therefore $\mathcal{L}^c \subseteq [\mathcal{MV} - scl(\mathcal{K})]^c$ implies that $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{L}$. Conversely, assume that $\mathcal{MV} - scl(\mathcal{K}) \subseteq \mathcal{L}$ where \mathcal{L} is a \mathcal{MVOS} and $\mathcal{K} \subseteq \mathcal{L}$. Then $\mathcal{L}^c \subseteq \mathcal{MV} - scl(\mathcal{K})$ where \mathcal{L}^c is a \mathcal{MVCS} and $\mathcal{L}^c \subseteq \mathcal{MV} - s - int(\mathcal{K}^c)$. Therefore, \mathcal{K}^c is a \mathcal{MVGSO} . This implies that \mathcal{K} is a \mathcal{MVGSCS} in U .

Theorem 4.34

A Micro Vague set \mathcal{K} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is a Micro Vague Generalized Semi Closed set if and only if $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{L}$ whenever \mathcal{L} is a Micro Vague Open set and $\mathcal{K} \subseteq \mathcal{L}$.

Proof: Assume that \mathcal{K} is a \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Let \mathcal{L} be a \mathcal{MVOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and $\mathcal{K} \subseteq \mathcal{L}$. Then \mathcal{L}^c is a \mathcal{MVCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ such that $\mathcal{L}^c \subseteq \mathcal{K}^c$. Since \mathcal{K}^c is a \mathcal{MVGSO} , $\mathcal{L}^c \subseteq \mathcal{MV} - s - int(\mathcal{K}^c)$. Therefore $\mathcal{K}^c \subseteq [\mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}^c))]$. Hence $\mathcal{L}^c \subseteq [\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K}))]^c$. This implies that $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{L}$. Conversely, let \mathcal{K} be a \mathcal{MV} set in U and $\mathcal{MV} - int(\mathcal{MV} - cl(\mathcal{K})) \subseteq \mathcal{L}$ whenever \mathcal{L} is \mathcal{MVOS} and $\mathcal{K} \subseteq \mathcal{L}$. Then $\mathcal{L}^c \subseteq \mathcal{K}^c$ and \mathcal{K}^c is a \mathcal{MVCS} . By hypothesis, $\mathcal{L}^c \subseteq [\mathcal{MV} - int(\mathcal{MV} - scl(\mathcal{K}))]^c$. Hence $\mathcal{L}^c \subseteq \mathcal{MV} - cl(\mathcal{MV} - int(\mathcal{K}^c))$ implies that $\mathcal{L}^c \subseteq \mathcal{MV} - s - int(\mathcal{K}^c)$. So that \mathcal{K}^c is a \mathcal{MVGSO} . Hence \mathcal{K} is a \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Micro Vague Generalized Semi Open sets

In this section we introduce Micro Vague Generalized Semi Open sets and some of their properties are discussed

Definition 5.1

A \mathcal{MV} Set A is said to be Micro Vague Generalized Semi open set (\mathcal{MVGSO}) in the \mathcal{MV} Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$, if the complement A^c of the \mathcal{MV} set is \mathcal{MVGSCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. (i.e) A \mathcal{MV} set A is said to be Micro Vague Generalized Semi Open set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ if $\mathcal{V} \subseteq \mathcal{MV} - s - int(A)$ whenever $\mathcal{V} \subseteq A$ and \mathcal{V} is Micro Vague Closed set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. The family of all Micro Vague Generalized Semi Open sets of $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is denoted by $\mathcal{MVGSO}(\mathcal{S})$.

Example 5.2: Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{ \langle \rho, (0.3, 0.4) \rangle, \langle \lambda, (0.1, 0.7) \rangle, \langle \theta, (0.2, 0.6) \rangle \}$ is a \mathcal{MVGSO} on U .

Theorem 5.3

Every Micro Vague Open Set is Micro Vague Generalized Semi Open Set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let A be Micro Vague Open set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. (i.e) $A = \mathcal{MV} - int(A)$. Let $V \subseteq A$ where V is a \mathcal{MVCS} in U . Since $\mathcal{MV} - int(A) \subseteq \mathcal{MV} - s - int(A)$, we have, $V \subseteq A = \mathcal{MV} - int(A) \subseteq \mathcal{MV} - s - int(A)$ which implies that $V \subseteq \mathcal{MV} - s - int(A)$ whenever $V \subseteq A$ and V is a \mathcal{MVCS} . Therefore, A is a \mathcal{MVGSO} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Remark 5.4

The Converse of the above theorem need not to be true which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{ \langle \rho, (0.6, 0.7) \rangle, \langle \lambda, (0.5, 0.7) \rangle, \langle \theta, (0.2, 0.3) \rangle \}$ is a \mathcal{MVGSO} in U but not \mathcal{MVOS} in U .



**Theorem 5.5**

Every Micro Vague Regular Open set is Micro Vague Generalized Semi Open set in the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let A be $\mathcal{MVR}\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. By hypothesis, we have $A = \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A))$. We know that for a $\mathcal{MVR}\mathcal{OS}$, $\mathcal{MV} - \text{int}(A) = \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A))$. This implies that $\mathcal{MV} - \text{int}(A) = A$. Therefore, A is a $\mathcal{MVG}\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. By theorem 5.3, we get that A is a $\mathcal{MVG}\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Remark 5.6

The Converse of the above theorem need not to be true which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.6, 0.8) >, < \lambda, (0.6, 0.8) >, < \theta, (0.2, 0.3) >\}$ is a $\mathcal{MVG}\mathcal{OS}$ in U but not $\mathcal{MVR}\mathcal{OS}$ in U .

Theorem 5.7

Every Micro Vague α Open set is Micro Vague Generalized Semi Open set in the Micro Vague Topological space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let A be $\mathcal{MV}\alpha\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Let $V \subseteq A$ where V is a \mathcal{MVCS} in U . By hypothesis, $A \subseteq \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))$. Since, $\mathcal{MV} - \text{int}(A) \subseteq A$, we have $A \subseteq \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))) \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$. Therefore, $V \subseteq A \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$ which means that $V \subseteq A \subseteq \mathcal{MV} - s - \text{int}(A)$. Hence A is a $\mathcal{MVG}\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Remark 5.8

The Converse of the above theorem need not to be true which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.3, 0.5) >, < \lambda, (0.1, 0.5) >, < \theta, (0.4, 0.8) >\}$ is a $\mathcal{MVG}\mathcal{OS}$ in U but since $A \not\subseteq \mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))$, A is not a $\mathcal{MV}\alpha\mathcal{OS}$ in U .

Theorem 5.9

Every Micro Vague Semi Open Set is Micro Vague Generalized Semi Open set in the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let A be $\mathcal{MVS}\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and let $V \subseteq A$ where V is a \mathcal{MVCS} in U . By hypothesis, $A \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$. This implies that $A \subseteq A \cap [\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))] = \mathcal{MV} - s - \text{int}(A)$. Therefore, $V \subseteq \mathcal{MV} - s - \text{int}(A)$, whenever $V \subseteq A$ and V is a \mathcal{MVCS} in U . Hence A is a $\mathcal{MVG}\mathcal{OS}$ in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Remark 5.10

The Converse of the above theorem need not to be true which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Then the \mathcal{MV} Set $\mathcal{K} = \{< \rho (0.1, 0.4) >, < \lambda, (0.1, 0.4) >, < \theta, (0.2, 0.3) >\}$ is a $\mathcal{MVG}\mathcal{OS}$ in U but since $A \not\subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$, A is not a $\mathcal{MVS}\mathcal{OS}$ in U .

Theorem 5.11

If A and B are the Micro Vague Generalized Semi Open Sets in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$, then $A \cup B$ is also a Micro Vague Generalized Semi Open set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let A and B be the $\mathcal{MVG}\mathcal{OS}$ s in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$, then we have $V \subseteq \mathcal{MV} - s - \text{int}(A)$ and $V \subseteq \mathcal{MV} - s - \text{int}(B)$ whenever $V \subseteq A$ and $V \subseteq B$ where V is a \mathcal{MVCS} in U . Therefore, we have $V \subseteq \mathcal{MV} - s - \text{int}(A) \cup \mathcal{MV} - s - \text{int}(B)$ and $V \subseteq A \cup B$. W.K.T, $\mathcal{MV} - s - \text{int}(A \cup B) \supseteq \mathcal{MV} - s - \text{int}(A) \cup \mathcal{MV} - s - \text{int}(B) \supseteq V$. This implies that





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$V \subseteq \mathcal{MV} - s - \text{int}(A \cup B)$. Therefore, we get that $V \subseteq \mathcal{MV} - s - \text{int}(A \cup B)$ whenever $V \subseteq A \cup B$ and V is a \mathcal{MVCS} in U . Hence $A \cup B$ is a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Example 5.12: Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Let $A = \{ \langle \rho, (0.2, 0.4) \rangle, \langle \lambda, (0.2, 0.4) \rangle, \langle \theta, (0.7, 0.8) \rangle \}$ and $B = \{ \langle \rho, (0.3, 0.5) \rangle, \langle \lambda, (0.1, 0.5) \rangle, \langle \theta, (0.4, 0.8) \rangle \}$ be \mathcal{MVGSOS} s in U . Then $A \cup B = \{ \langle \rho, (0.3, 0.5) \rangle, \langle \lambda, (0.2, 0.5) \rangle, \langle \theta, (0.7, 0.8) \rangle \}$ is also a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ since $V \subseteq \mathcal{MV} - s - \text{int}(A \cup B)$ whenever $V \subseteq A \cup B$ and V is a \mathcal{MVCS} in U .

Remark 5.13

The intersection of any two Micro Vague Generalized Semi Open sets in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ need not to be a Micro Vague Generalized Semi Open set which is seen in the following example. Let us consider the Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ in the example 4.4. Let $A = \{ \langle \rho, (0.3, 0.5) \rangle, \langle \lambda, (0.3, 0.5) \rangle, \langle \theta, (0.2, 0.3) \rangle \}$ and $B = \{ \langle \rho, (0.5, 0.7) \rangle, \langle \lambda, (0.5, 0.7) \rangle, \langle \theta, (0.7, 0.8) \rangle \}$ be \mathcal{MVGSOS} s on U . Then $A \cap B = \{ \langle \rho, (0.3, 0.5) \rangle, \langle \lambda, (0.3, 0.5) \rangle, \langle \theta, (0.2, 0.3) \rangle \}$ is not a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ since $V \not\subseteq \mathcal{MV} - s - \text{int}(A \cap B)$ whenever $V \subseteq A \cap B$ where V is a \mathcal{MVCS} in U .

Theorem 5.14

If A is a Micro Vague Generalized Semi Open Set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and if $\mathcal{MV} - s - \text{int}(A) \subseteq B \subseteq A$, then B is a Micro Vague Generalized Semi Open Set in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Proof: Let A be \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Since $\mathcal{MV} - s - \text{int}(A) \subseteq B \subseteq A$, we have $A^c \subseteq B^c \subseteq (\mathcal{MV} - s - \text{int}(A))^c = \mathcal{MV} - s - \text{cl}(A^c)$. Again since, A^c is a \mathcal{MVGSOS} and by theorem 4.31, we have B^c is a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Hence B is a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Theorem 5.15

A Micro Vague set A of a Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is a Micro Vague Generalized Semi Open set if and only if $B \subseteq \mathcal{MV} - s - \text{int}(A)$ where B is a Micro Vague Closed set and $B \subseteq A$.

Proof: Assume that A is \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Let B be a \mathcal{MVCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ such that $B \subseteq A$. Then B^c is a \mathcal{MVOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ such that $A^c \subseteq B^c$. Since A^c is a \mathcal{MVGSOS} , we have $\mathcal{MV} - s - \text{cl}(A^c) \subseteq B^c$. Hence, we have $\mathcal{MV} - s - \text{cl}(A^c) = (\mathcal{MV} - s - \text{int}(A))^c \subseteq B^c$. Therefore, $(\mathcal{MV} - s - \text{int}(A))^c \subseteq B^c$ implies that $B \subseteq \mathcal{MV} - s - \text{int}(A)$. Conversely, assume that $B \subseteq \mathcal{MV} - s - \text{int}(A)$ where B is a \mathcal{MVCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and $B \subseteq A$. Then $(\mathcal{MV} - s - \text{int}(A))^c \subseteq B^c$ where B^c is a \mathcal{MVOS} and $\mathcal{MV} - s - \text{cl}(A^c) \subseteq B^c$. Therefore, A^c is a \mathcal{MVGSOS} . This implies that A is a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.

Theorem 5.16

A Micro Vague set A of a Micro Vague Topological Space $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ is a Micro Vague Generalized Semi Open set if and only if $B \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$ whenever B is a Micro Vague Closed set and $B \subseteq A$.

Proof: Assume that A is a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. Let B be a \mathcal{MVCS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and $B \subseteq A$. The B^c is a \mathcal{MVOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ such that $A^c \subseteq B^c$. Since A^c is a \mathcal{MVGSOS} , $\mathcal{MV} - s - \text{cl}(A^c) \subseteq B^c$. Therefore, $\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A^c)) \subseteq B^c$. Hence $(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))^c \subseteq B^c$. This implies that $B \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$. Conversely, let A be a \mathcal{MV} set of $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$ and $B \subseteq \mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A))$ whenever B is a \mathcal{MVCS} and $B \subseteq A$. Then $A^c \subseteq B^c$ is a \mathcal{MVOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$. By hypothesis, $(\mathcal{MV} - \text{cl}(\mathcal{MV} - \text{int}(A)))^c \subseteq B^c$. Hence $\mathcal{MV} - \text{int}(\mathcal{MV} - \text{cl}(A^c)) \subseteq B^c$ implies that $\mathcal{MV} - s - \text{cl}(A^c) \subseteq B^c$. So that A^c is a \mathcal{MVGSOS} . Hence A is a \mathcal{MVGSOS} in $(\mathcal{U}, \tau_R(\mathcal{S}), \eta_R(\mathcal{S}))$.





CONCLUSION

In this paper, the new types of sets in Micro Vague Topological Spaces such as Micro Vague Generalized Closed set, Micro Vague Generalized Semi Closed (Open) set, Micro Vague Generalized Pre-Closed (Open) Set, Micro Vague Generalized α Closed (Open) Set, Micro Vague Generalized Semi-Pre-Closed (Open) set are introduced. Some of the basic theorems and characterizations are derived and investigated with the suitable numerical examples.

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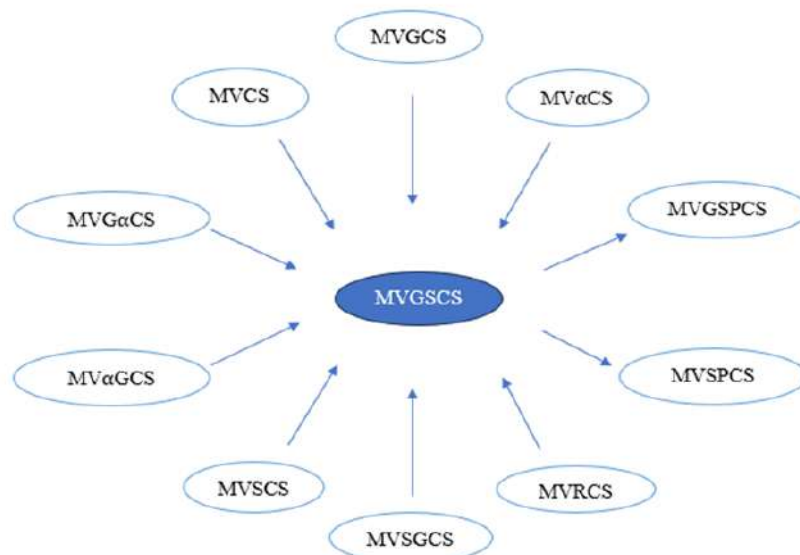


Fig:1





Mapping the Landscape of Government Policies and Electric Vehicles: A Bibliometric and Visualization Analysis

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ABSTRACT

This study employs bibliometric and visualization approaches to map the developing research on government policies and electric vehicles (EVs), analyzing 207 papers from the Scopus database. Research trends, well-known authors, prominent countries, collaborations, top journals, and most globally cited documents were identified. While *Sustainability* and *Energy Policy* are the leading journals in EV policy research, Wang H. is recognized as the most prolific contributor. China is the leading contributor, highlighting its crucial role in developing EVs and innovative policies. A landmark study in this area, "Optimal fast charging station placing and sizing," by Barzani *et al.* (2014), has impacted discussions on EV policy frameworks and adoption. The study employs Lotka's Law to examine author productivity and Bradford's Law to verify that key research is concentrated in particular publications. Findings show that a few authors are exceptionally prolific, consistent with Bradford's Law but different from Lotka's Law. a) Electric vehicle infrastructure and technology, b) Sustainability and government policies, c) Government policy and adoption, d) Purchase intention and barriers to adoption, e) Environmental impact and transportation, and f) China's role in EV, are the six thematic clusters that emerged. The study provides researchers and policymakers with useful insights using keyword co-occurrence analysis, laying the groundwork to address issues and foster innovation in the EV ecosystem.

Keywords: Electric vehicles, Government policies, Sustainable transportation, Bibliometric analysis, Sustainability, Scientific mapping.





INTRODUCTION

In recent years, there has been a major global shift toward sustainable transportation due to the growing urgency of reducing fossil fuel dependency and mitigating climate change. Due to their widespread use, fossil fuels including coal, oil, and natural gas have seriously harmed the environment, contributing to rising emissions and global warming (Yang *et al.*, 2022). Transportation is a major source of air pollution and CO₂ emissions, particularly internal combustion engines, which account for 25% of global CO₂ emissions and 12% of India's energy-related emissions (Khurana, 2020; Ayodele, 2020). Compared to internal combustion engines, electric vehicles (EVs) offer a greener option (Tiep *et al.*, 2023), the increasing adoption of electric vehicles (EVs), which are viewed as a critical solution for lowering greenhouse gas emissions, enhancing energy efficiency, and encouraging clean energy utilization in the automotive sector, is one of the significant responses to the environmental and economic challenges (F. Wang *et al.*, 2020). Existing research indicates that promoting the use of electric vehicles needs strong regulatory support (Bas *et al.*, 2022; Begley *et al.*, 2016; Setiawan *et al.*, 2022; Qian *et al.*, 2019). The market for electric vehicles is growing, and government policies are crucial in determining how quickly and how much this shift happens. Governments all around the world have advanced the adoption of EVs through the introduction of regulatory frameworks, incentives, subsidies, and infrastructure assistance (Hardman *et al.*, 2016). The EV industry's innovation progressions and market dynamics have been significantly impacted by government interventions, specifically in infrastructure development, tax rebates, emission standards, and subsidies (W. Li *et al.*, 2019). These regulations not only motivate consumers to switch from traditional internal combustion engine vehicles to electric alternatives, but they also support research and development in the automotive sector to create more affordable and efficient EV technologies (Sierzchula *et al.*, 2014). Automakers have expanded their spending in the development and production of electric vehicles, while businesses have modified their business models to take advantage of government-backed incentives and keep up with changing rules (Paul *et al.*, 2015).

In recent years, the academic literature studying the confluence between government policy and the electric vehicle market has increased dramatically. Researchers have investigated several facets of this connection, such as the role of public-private partnerships, the efficacy of various policy instruments, and the difficulties in developing a strong charging infrastructure (W. Li *et al.*, 2017; Liao *et al.*, 2017). Despite this, a thorough bibliometric analysis is still required to map out the terrain of previously published works and illustrate the conceptual framework of this field of study. The term "Bibliometrics" was created by Pritchard in 1969 as a replacement for the less widely used and more ambiguous word "statistical bibliography" (Groos & Pritchard, 1969; Hood & Wilson, 2001). Increased accessibility to tools, databases, and software, as well as the expansion of bibliometric analysis applications beyond information science, like business research, are the two main factors driving the popularity of bibliometric analysis (Donthu *et al.*, 2021). Bibliometric analysis is a quantitative technique that examines co-authorship networks, keyword trends, and citation patterns in the academic literature (Aria & Cuccurullo, 2017). This method reveals new trends, patterns of collaboration, and knowledge gaps in addition to highlighting the most significant papers and researchers on the subject. We can map the research structure on government policies and electric vehicles by combining bibliometric analysis with visualization techniques. This allows us to get important insights into the evolution of this quickly evolving field. The purpose of this work is to perform a thorough bibliometric and graphical analysis of the scholarly literature on the laws about electric vehicle policy. The goal of this study is to present a comprehensive overview of the current state of the field, identify notable research clusters, and provide options for future research by analyzing key themes, influential authors, and citation networks. We hope that our analysis will advance knowledge of how government actions affect the market for electric vehicles and advance environmentally friendly transportation. In this study, the following research questions (RQs) are investigated:

RQ1: What are the annual publication trends in government policies and electric vehicles in the concerned areas?

RQ2: Who are the most productive participants (journals, authors, and countries) in the field?

RQ3: What are the most prominent publications in the field?

RQ4: Do the findings align with Lotka and Bradford's bibliometric laws?

RQ5: What possible avenues for further study exist in the field of government policies and electric vehicles?





RESEARCH METHODOLOGY

A review study's objectives are to define the present level of knowledge in a particular field of study, pinpoint knowledge gaps, and compile the results of earlier investigations. Numerous forms of literature reviews are available, such as thematic-based reviews, descriptive reviews (Batra *et al.*, 2022), systematic evaluations (Khatib, 2021), and bibliometric reviews developed by Pritchard in 1969 (Groos & Pritchard, 1969). Through the quantitative analysis of content, bibliometric evaluations improve objectivity by examining massive data sets to identify patterns and areas for future research (Donthu *et al.*, 2021; Joshipura & Wats, 2023). This method reduces subjectivity and aids in identifying the most significant contributions made by scholars (Zupic, 2015). The research integrates two bibliometric techniques: performance analysis, which assesses several aspects of publications and citations to provide information about productivity and impact, and scientific mapping, which visualizes the research landscape by graphically representing the field's dynamics and structure (Gao *et al.*, 2021). Bibliometric laws, such as Lotka's law and Bradford's law, are applied in the study to ascertain the core group of journals and the authors' scientific production in this field of research. The study uses the R Bibliometrix (Aria & Cuccurullo, 2017) and Vosviewer (V. Eck & Rousseau, 2014) for analysis. R is useful for bibliometric research because of its many integrated packages and regular updates (Forliano *et al.*, 2021). VOS viewer is a program known for its extensive analysis and visualization capabilities; it specializes in the graphical display of bibliometric maps, including density, co-occurrence, and trend analysis (N. J. van Eck & Waltman, 2010; Ullah *et al.*, 2023). Figure 1 presents the structure of the data used in the study.

Database, search strategy, and screening procedure

Scopus and Web of Science are two well-known databases but Scopus is used in this study because it is the largest repository of peer-reviewed literature, is more comprehensive, and has a greater number of journals, in comparison to the Web of Science database (Bhat & Qureshi, 2023; López-Illescas *et al.*, 2008; Farooq, 2024; Aghaei Chadegani *et al.*, 2013; Kumar *et al.*, 2024; Maral, 2024; Zainuddin & Lui, 2022). Moreover, the Scopus database has been used by numerous researchers in social science (Saini, 2023; Gora *et al.*, 2024; Dhingra & Batra, 2024; V. Kumar *et al.*, 2021; Donthu *et al.*, 2020) to conduct review studies. The search was conducted on October 07, 2024, for extraction of data from the Scopus database, for the period 2010-2024. Firstly, the search string used in the study for extraction of data was: ("Government policies" OR "Governmental strategies" OR "Regulatory policies" OR "Governing principles" OR "Legislative measures") AND ("Electric vehicles" OR "Electric cars" OR "Electric mobility" OR "Electric automobile" OR "Electric transport" OR "Green vehicles" OR "Eco-friendly vehicles"). It resulted in 428 documents. Additionally, to minimize non-significant articles and to ensure constant data cleanliness, criteria for inclusion and exclusion were incorporated into our search results. The next inclusion criterion is the period for which the study is conducted. The analysis took into consideration data from 2010 to 2024. It resulted in 413 documents. The next inclusion criteria belong to the subject area and included the subjects, "Business and Management," "Economics," "Social Sciences," and "Environmental Sciences." It results in 231 documents. Further refinement was done based on document type. Journal articles, conference papers, and review articles were chosen for inclusion in the study. However, books, book chapters, and review articles were not included since they are not considered primary sources. The language is connected to the additional inclusion requirements. The study selected all documents written exclusively in English. Articles written in any other language were excluded. It resulted in 213 articles. After analyzing the full text of each article, 06 articles were removed which are considered less relevant to the study. It resulted, in a total of 207 articles, which were further analyzed to derive the conclusion. The data file was downloaded in the csv. File format from the Scopus database. The file was then exported to R-Studio biblioshiny and VOS viewer for analysis.

ANALYSIS AND RESULTS

Overview of Data and Publication Trend

Table 1 provides the summary of the 207 articles collected from the Scopus database from 2011 to 2024 (till October). The data was originated from 115 sources and consists of 654 authors. The average number of citations per document





was 25.87 and the number of documents increasing yearly with a growth rate of 15.49%. Figure 2 depicts the publication trend of articles concerning government policies and electric vehicles. Initially, the figure shows a fluctuating trend with six articles published in 2011 and then the trend goes downward. The rise in publication on this topic started in 2015 and shows a remarkable increase with 38 articles in 2022. Then, till October 2024, 39 articles were published on this topic. This growing trend depicts that government policies about electric vehicles are likely to remain a key area of study because of their crucial role in influencing the direction of sustainable transportation.

Analysis of Authorship

The information regarding the top 10 most productive authors in government policies and electric vehicles research, from the point of view of publications and citations, is given in Table 2. Out of the 654, the top 10 productive authors were chosen by taking into account those who had at least two publications. Wang H and Li J have lead in publications with 6 and 5 articles respectively. Moreover, Hao H, Li L, Li Y, Liu Y, Wang Y, and Zhou Y have authored 4 articles each. The remaining two, i.e., Harichandan S and Kar SK have published 3 articles each. Among all authors, Hao H has lead with 521 citations. Among others, three authors namely, Wang H, Li J, and Zhou Y have more than 200 citations, i.e., 356, 233, and 227 citations respectively. This data illustrates the expanding interest in this topic. These authors have actively published research over the past fourteen years, exhibiting a substantial dedication and contribution of authors.

Country Analysis

Table 3 shows the top 10 most productive countries based on publications and citations. The criteria for inclusion are a minimum of five publications of each country. This results in 24 countries out of the total of 41 countries. Among the 24 countries, the top 10 countries are depicted in table 3. It describes how China emerged as the top country in the world for publications and citations. China has the highest number of published articles, i.e., 211, and received the most remarkable citations, i.e., 2173. India, the United States, and Indonesia came next with 105, 63, and 47 publications, respectively, and 337, 251 and 78 citations, respectively. Notably, the UK and Australia have received 207 and 192 citations respectively despite publishing fewer papers i.e., 24 and 30 respectively, indicating the prominence of these countries in the field of GP and EV research. It can be observed from the table that the countries actively involved in research related to government policies and electric vehicles are fairly represented by the developing and developed nations. The number of publications by each country suggests that worldwide, both developing and developed nations are actively participating in the field. This indicates a global interest and commitment to exploring the crucial link of these topics.

Source Analysis

Based on the criteria of having at least three papers with a minimum of three citations, Table 4 illustrates the top 10 most prominent journals. This results in 14 out of a total of 115 journals. Based on the observation of the table, the journal "Sustainability" has the highest number of publications i.e., 22, and received 378 citations. The journal "Energy Policy" has received a remarkable 1,025 citations despite publishing fewer i.e., 15 papers. When the number of citations per publication is taken into account, "Journal of Cleaner Production," "Applied Energy" and "Sustainability," rank second, third, and fourth respectively, demonstrating their value and prominence in this area. Additionally, when several publications are taken into account, then "Energy Policy," "Journal of Cleaner Production," and "Transportation Research Part A: Policy and Practice" take the second, third, and fourth position respectively. These outcomes provide insight into the top journals in GP and EV research.

Document Analysis

Applying the criterion of at least 35 citations per article, Table 5 displays the top 10 most notable publications based on the number of citations received. It resulted in 45 out of a total of 207 articles. Based on the table's observations, Barzani *et al.* (2014) have the highest citation count, to taling 429. This study explored the role of government regulations in the growth and prosperity of EV infrastructure, especially when it comes to the construction of fast charging stations. It emphasizes how crucial public sector support is in lowering development costs and promoting private sector participation. Meanwhile, the articles of Sang *et al.* (2015) and Zhang *et al.* (2011) take the second and



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third positions with more than 200 citations, i.e., 254 and 214 citations respectively. Sang et al. (2015) highlight the pivotal role of government policies in encouraging electric vehicles (EVs) in Malaysia as a means of lowering carbon emissions and the country's dependency on fossil fuels. The study of Zhang et al. (2011) sheds light on the significance of the government's long-term plans and encouraging laws to address environmental issues and propel the expansion of the EV market in China.

Bradford's Law

Bradford's law assessed the distribution of articles by journals and identified the key sources for a particular topic (Geophysics, 1985). Accordingly, journals can be categorized into three zones, with one-third of all papers found in each zone (Bhayani, 2024; Tepe et al., 2022). The Core zone, Zones 1 and 2, have almost the same number (i.e., one-third) of articles (Singh et al., 2016). However, as we move from the core zone to Zone 1, the number of journals rises, indicating that a small number of journals are considered "core zone journals" and act as the drivers of any given area. This law states that a limited number of sources, which represents the "core sources" driving the topic, producing the initial one-third of articles. Zone I comprises more sources for the next one-third of the articles, while Zone III displays the final one-third of articles and the greatest number of sources. As shown in Figure 3, the main sources of publications on government policies and electric vehicle research are "Sustainability (Switzerland)", "Energy Policy", "Journal of Cleaner Production", "Transportation Research Part A", "Applied Energy", "Energy" and "E3S web of conferences". Additionally, 207 articles were published in 115 journals, according to the data in Table 6. The initial set of 7 prestigious journals published 69 articles, considered core journals on the topic; 70 articles were published by the second group of 40 journals, which exist in Zone 1; 68 articles were published by the next group of 68 journals, which lies in Zone 2. According to these results, about one-third of research papers belong to each group, and as one moves from one zone to the next, the number of journals rises. The findings in this section support the claim that research on GP and EVs is consistent with Bradford's law principles (Tepe et al., 2022).

Lotka's Law

The distribution of articles written in a specific field of study is described by Lotka's law (Lotka, 1926), a bibliometric law used in this study. According to this law, 60% of authors in a certain field of study have only one publication, 15% have two, and 6.6% have three (Tepe et al., 2022; Wang & Guo, 2022). Table 7 shows the percentage of authors based on the number of publications. The data revealed that out of the total, 88.5% of authors have produced only one article which is far away from the required percentage of 60% according to Lotka's law. 8.7% of authors have written two articles, which is quite less than the benchmark of 15% and 1.5% have written three articles, which also falls short of the benchmark of 6.6%, as per the law. Figure 4 shows the difference between Lotka's distribution and the observed distribution. The dashed line in the figure shows the theoretical distribution according to Lotka's law, whereas the solid line reflects the actual observed data. The sharp drop-off around the starting point of the graph shows that a large percentage of authors contribute only one or two articles, while a far smaller percentage of authors contribute more than two publications. As per the results, the research output of authors in GP and EVs deviates from Lotka's law.

Three-field plot

Sankey diagrams, sometimes referred to as three-field plots, are used to show relationships between three fields and complex flow situations (Riehmman et al., 2005; Georgescu & Chirit, 2024). The relationships between countries (left), authors (middle), and keywords (right) are presented in detail in Figure 5, which is based on the well-known Sankey diagram. Each box's length in the figure indicates the overall frequency of links with other boxes. The figure shows the most popular terms in this topic, the authors' contributions, and their global collaborations. The total frequency of connections to other boxes is reflected in the length of each box. The results show that China represents sixteen of the top twenty authors (Wang H., Li J., Wang Y., Hao H., Li L., Zhou Y., Ouyang M., Zhang J., Liu D., Wang J., Li Y., Liu F., Liu Y., Pan H., Li S., Qian L.). This outcome is related to the findings of Table 3 which represents that China is dominating in publications about GP and EVs. The USA represents nine authors. Additionally, the USA, Turkey, and Malaysia represent a considerable number of authors. These authors are experts in their respective areas including





"electric vehicles", "government policy", "new energy vehicles", and "sustainable development". These terms are extremely popular in the study's literature.

Country Collaboration Analysis

Country collaboration is a popular bibliometric method for examining a country's social structure and collaboration tendencies among nations (Ghura *et al.*, 2022). It serves as an example of the intellectual networks that propel scientific progress and improve the quality of research (Joshipura & Wats, 2023; Khatib *et al.*, 2023). Figure 6 shows the collaboration map of nations in the GP and EVs domain. The grey color denotes no publications and the light blue to dark blue spectrum shows an increasing number of published papers. The network of international cooperation is indicated by the red lines. As evident from Table 8, the strongest connection is found between the USA and China, as thirteen papers have been co-authored by authors from these two nations. China has a significant network of collaboration with most countries including Hong Kong and the United Kingdom, with authors of these countries have co-authored four papers. As depicted by red lines in the figure, other countries are also involved in the collaboration network including Korea, France, Singapore, India, Thailand, Japan, and the UK.

Keyword analysis

An essential scientific technique for finding links between different study areas and assisting in the discovery of new research trends is the keyword co-occurrence network (Q. Wang, 2018; Saha *et al.*, 2020; Ülker *et al.*, 2023). Figure 7 shows a graphical representation of the network that illustrates the frequency of keyword co-occurrence. Using the criterion of minimum 4 occurrences of author keywords, 22 out of 706 author keywords met the threshold. The final network, which is seen in Figure 7, has 22 nodes that have been arranged into six different clusters based on VOS viewer analysis. The fundamental study themes that these six clusters represent are –(a) "Electric Vehicle Infrastructure and Technology", (b) "Sustainability and Government Policies", (c) "Government Policy and Adoption", (d) "Purchase Intention and Barriers to Adoption", (e) "Environmental Impact and Transportation" and (f) "China's Role in EV Development".

Cluster 1: Electric Vehicle Infrastructure and Technology

In the keyword network, this cluster is related to six keywords, 'battery electric vehicle', 'charging infrastructure', 'electric vehicle', 'policy', 'sustainable transportation', and 'system dynamics'. Several research on this cluster concentrated on the significance of electric vehicle technology, especially about government regulations and electric vehicles (IEA, 2021; International & Agency, 2023; Paul Sathiyar *et al.*, 2022; Shafiei *et al.*, 2017).

Cluster 2: Sustainability and Government Policies

This cluster, which focuses on the relationship between government policies and electric vehicles, is the most noticeable and consists of the four keywords "circular economy," "electric vehicles," "government policies," and "sustainability." A careful examination of the related literature showed that the complex relationship between these components has received a lot of attention from academics (H. Li & Li, 2021; Basu, 2023; Leydesdorff & Zawdie, 2010).

Cluster 3: Government Policy and Adoption.

The cluster encompassed the three keywords related to 'adoption', 'attitude', and 'barriers' focused on government policies and electric vehicle adoption. Various studies related to this cluster revealed that regulatory initiatives including the transportation policies such as parking incentives, fuel tax, and subsidies, play a crucial role in increasing market penetration for electric vehicles (Abas & Tan, 2024; Zaino *et al.*, 2024; Javadnejad *et al.*, 2024; Munachi Chikodili Ugwu & Adefolake Olachi Adewusi, 2024).

Cluster 4: Purchase Intention and Barriers to Adoption.

This cluster encompassed the three keywords, 'China', 'new energy vehicle', and 'purchase intention' which are related to the purchase intention of customers and the barriers involved in the adoption of electric vehicles. The studies suggest several factors including consumer attitudes, environmental concerns, risk perception of consumers, and attitude towards innovation, influence the purchase intention of consumers, and the barriers to EV adoption



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include price, charging issues, and range anxiety (Zaino *et al.*, 2024; Ikram, 2022; Lashari *et al.*, 2021; Dutta & Hwang, 2021; Change *et al.*, 2024).

Cluster 5: Environmental Impact and Transportation.

In the keyword network, this cluster consists of three keywords, 'environment', 'government policy', and 'transportation'. This cluster emphasizes the environmental impact of electric vehicles in the wider context of transportation. International transportation regulations support electric vehicle adoption and are viewed as an essential strategy for attaining environmental sustainability. Lee *et al.* (2020) explored the effect of electric vehicle adoption on urban air quality (Timmers & Achten, 2018) and discussed the significance of clean energy sources in maximizing the positive environmental impact (R. R. Kumar & Alok, 2020).

Cluster 6: China's Role in EV Development.

This cluster consists of three keywords, 'discrete choice model', 'sustainable development', and 'transportation policy'. Several research studies in this field focused on China's manufacturing capabilities, market dynamics, government policies, its position as a worldwide leader in the EV sector, and its role in EV development (Zhang *et al.*, 2017; F. P. Wang *et al.*, 2017; W. Li *et al.*, 2019).

Thematic evolution

While investigating the connection between GP and EVs, R Studio's Biblioshiny was utilized in addition to VOSviewer to examine the commonly used keywords at different phases of study progress. Figure 8 illustrates the thematic evolution, created using Biblioshiny's "author keywords" and offers insights into the changing conceptual framework of GP and EV research from 2011 to 2024. To illustrate how significant and essential themes emerged, a three-field plot (Figure 8) was created. To highlight the constant development of research themes in this area, this analysis highlights the relationships and shifts between themes over three different periods: 2011–2012, 2013–2020, and 2021–2024. 2011–2012: In this period, two primary research themes emerged: "Fuel consumption" and "Electric vehicles." These themes centred around initial discussions regarding energy usage and the growing prominence of electric vehicles (EVs). From 2013 to 2020, electric vehicles emerged as a significant theme, encompassing several subthemes such as: "Electric vehicles," "Automobile manufacturing," "Charging stations," "Electric utilities," and "Battery electric vehicles." This period marks a more detailed exploration of EV-related infrastructure (e.g., charging stations), industry involvement (automobile manufacturing), and technology improvements (battery electric vehicles). 2021–2024: In this recent timeframe, the research landscape broadened to include the themes related to GP and EVs. The themes that emerged in this period are: "Electric vehicles", "Mobility", "Industry policies", "Automotive industry", "Technology adoption", "Charging infrastructure", "Emission reduction", "Sustainability", "Public policies" and "Government policies". The studies produced within this time frame highlight the importance of sustainability, mobility, and public policies, indicating a move toward more significant policy issues and societal impacts. Additionally, the implementation of emission-reducing technology and techniques is being prioritized, indicating the growing significance of policy-driven approaches in the EV industry and sustainable transportation.

DISCUSSION AND CONCLUSION

The results of this bibliometric and visual study offer a thorough mapping of the academic literature on EVs and government policy, emphasizing several noteworthy patterns and trends. The study of governmental regulations and electric vehicles has seen a sharp increase in interest in recent years. The dramatic increase in publications on this subject over the past ten years demonstrates how the urgent need to fight climate change and lessen reliance on fossil fuels has led to an increasing global interest in electric mobility. This bibliometric analysis aimed to provide a clear overview of the repository's structure and the significant conceptual literature on GP and EVs. The evolution of the FI and SD domain from 2011 to 2024 is highlighted in this study by analyzing 207 documents indexed in Scopus using VOS viewer and the R bibliometric tool. In response to RQ1, the study analyzed the annual publication trend in the field of GP and EVs in the subject area of "Business and Management", "Economics", "Social Sciences" and



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"Environmental Science". 207 Scopus-indexed publications from 2011 to 2024 were included in the data set. The analysis revealed that the publications in the field started increasing in 2015 and there was a sharp upswing in publications in 2022. Although some publications declined in 2023, they started rising continuously and the publications of 2024 till October are more than the publications of 2023. This rise in study is a reflection of how EVs are becoming more and more important on national and worldwide policy agendas due to infrastructure development, government incentives, and EV technical breakthroughs. It shows increased scholarly interest in assessing how well policies encourage the adoption of EVs. In response to RQ2 regarding the prominent journals, authors, and countries, it was found that the "Sustainability" journal is the most notable in the number of publications, and the "Energy Policy" journal is the most prominent in terms of citations received. The process of identification of notable authors is a crucial component in understanding the structure of a topic. Through authorship analysis, it was found that Wang H. and Li J. emerged as prominent contributors while Hao H. received the highest citations, highlighting their significant contributions to the field of GP and EVs research. It was observed through the study that China produced the most scholarly work, followed by India and Nigeria, reflecting the cooperative research initiatives. In response to RQ3, it was found that the most cited work was "Optimal fast charging station placing and sizing" by Barzani *et al.* (2014). This study explored the significance of government regulations to the growth and prosperity of EV infrastructure. It emphasizes how crucial public sector support is in lowering development costs and promoting private sector participation. To address RQ4, the study employed bibliometric laws and compared the results with Bradford's and Lotka's laws. The results supported Bradford's law but showed a discrepancy with Lotka's law.

According to the country collaboration analysis, China and the USA have co-authored thirteen documents, which were the maximum of the two countries in the GP and EV literature. Subsequently, keyword analysis provided information about the current state of research and suggested possible directions for further investigation in this specific area of study. Subsequently, six thematic clusters were identified through this analysis: "Electric Vehicle Infrastructure and Technology", "Sustainability and Government Policies", "Government Policy and Adoption", "Purchase Intention and Barriers to Adoption", "Environmental Impact and Transportation", "China's Role in EV development". Thematic clusters identified through keyword analysis provide a guide for further research in this area. Furthermore, we looked at the thematic evolution, aiding in addressing the last research question (RQ5). It was investigated over three different periods: 2011-2012, 2013-2020 and 2021-2024. Between 2011 and 2012, fuel consumption and electric vehicles were the primary topics of discussion, indicating that interest was divided between traditional fuel issues and the emerging electric vehicle (EV) market. From 2013 to 2020, the electric vehicle theme was becoming more and more popular at this time, and new topics including car manufacturing, charging stations, and battery electric vehicles are also starting to emerge. This is a reflection of the industry's increasing emphasis on building up EV production and infrastructure. In the latest period from 2021 to 2024, while electric vehicles remain a primary emphasis, new topics such as mobility, technological adoption, the automotive industry, highway policies, and sustainability also surface in the most recent era. This points to a more comprehensive strategy in which the emphasis has shifted from the manufacture of vehicles to more comprehensive regulatory, technological, and sustainability considerations about the EV ecosystem. This study has certain limitations even if it provides insightful information. It focuses solely on publications that are indexed in Scopus. Other widely used databases such as WOS (Zhu and Liu, 2020; Li *et al.*, 2018) and PubMed, frequently used for bibliometric analysis and research evaluation, were not used in the study, they could be included in future studies. Second, the study only addresses bibliometric analysis. Future research should examine several methods of systematic literature reviews (SLRs), such as reviews that are driven by theory, methodology, or meta-analysis (Bilal *et al.*, 2018), even if the review procedure provided by bibliometric analysis is transparent, quantitative, and reproducible. Despite the small sample of papers in this study, its findings and implications offer an initial point for further research.

Study Implications

Theoretical implications

With its strong theoretical foundation, the current bibliometric analysis on government policies (GP) and electric vehicles (EVs) research provides insightful information. Through this study, future researchers can find important



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themes, as given in Table 9 that will improve the discussion around GP and EVs by examining a range of factors, including top authors, nations, and the most cited documents. This study tracks the growth of this topic from 2011 to 2024 and offers thorough coverage of work that looks at the connection between GP and EVs. The study's thematic evolution analysis also helps scholars discover subjects that have been thoroughly examined and those that need more research. The study notably identifies China, India, and the USA as the key contributors, with China and the USA collaborating on important projects. This illustrates how research results and collaborations are increasing in emerging economies. It also raises the possibility of doing cross-national comparative research in the future.

Practical implications

The study emphasizes key areas to deliver actionable insights. Policymakers can address obstacles to EV adoption, such as charging infrastructure and consumer attitudes, by concentrating on improving EV infrastructure and technology through tailored regulations and incentives. Sustainability in EV production and use can be encouraged by incorporating circular economy ideas into governmental regulations. Regarding market strategy, international cooperation, policy innovation, and cross-border cooperation, other countries can learn a lot from China's dominant position in the EV sector. These insights can help to shape future regulations, enhance consumer acceptance, and mitigate environmental effects for researchers and industry stakeholders. Additionally, the study offers potential avenues for future research, as shown in Table 6, based on a thorough examination of keyword analysis.

Conflict of Interest

The authors declare no conflict of interest. The writing and content of this article is the sole responsibility of authors.

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Table.1: Overview of the data set

Description	Results
Main Information About Data	
Times pan	2011:2024
Sources (Journals, Books, etc)	115
Documents	207
Annual Growth Rate %	15.49
Document Average Age	3.5
Average citations per doc	25.87
References	10399
Document Contents	
Keywords Plus (ID)	1220
Author's Keywords (DE)	706
Authors	
Authors	654
Authors of single-authored docs	13
Authors Collaboration	
Single-authored docs	13
Co-Authors per Doc	3.66
International co-authorships %	28.02
Document Types	
Article	162
Conference paper	31
Review	14
Source: Created by authors	

Source: Created by authors

Table.2: Top 10 most productive authors

Authors	Articles	Citations	Country	Affiliation
Wang H	6	356	China	Tsinghua University, Beijing, China
Li J(J. Li <i>et al.</i> , 2020)	5	233	China	Wuhan University of Science and Technology, Wuhan, China





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Hao H(Hao <i>et al.</i> , 2020)	4	521	China	Tsinghua University, Beijing, China
Li L(L. Li <i>et al.</i> , 2020)	4	29	China	Wuhan University of Technology, Wuhan, China
Li Y(Y. Li, 2016)	4	74	China	China University of Petroleum-Beijing, Changping, Beijing, China
Liu Y(Liu & Kokko, 2010)	4	31	China	North China Electric Power University, Beijing, China
Wang Y	4	186	China	Shanghai University, Shanghai, China
Zhou Y(Zhou <i>et al.</i> , 2024)	4	227	New York	Stony Brook University, Stony Brook, New York
Harichandan S(Harichandan & Kar, 2023)	3	68	India	Rajiv Gandhi Institute of Petroleum Technology, Amethi, Uttar Pradesh, India
Kar SK	3	68	India	Rajiv Gandhi Institute of Petroleum Technology, Amethi, Uttar Pradesh, India

Source: Created by authors

Table.3:Top 10 most contributing nations

Rank	Country	No. of publications	Citations	Developing/Developed
1	China	211	2173	Developing
2	India	105	337	Developing
3	USA	63	251	Developed
4	Indonesia	47	78	Developing
5	Turkey	35	94	Developing
6	Australia	30	192	Developed
7	South Korea	27	71	Developed
8	UK	24	207	Developed
9	Malaysia	19	104	Developing
10	Thailand	19	5	Developing

Source: Created by authors

Table.4:Top 10 most prominent journals

Rank	Journal	No. of Publications	Citations	Average citation per publication
1	Sustainability (Switzerland)	22	378	17
2	Energy Policy	15	1025	68
3	Journal of Cleaner Production	12	771	64
4	Transportation Research Part A: Policy and Practice	6	301	50
5	Applied Energy	5	515	103
6	Energy	5	273	54
7	E3s Web of Conferences	4	3	0.75
8	International Journal of Sustainable Transportation	4	134	33





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9	IOP Conference Series: Earth and Environmental Science	4	5	1.25
10	Transportation Research Part D: Transport and Environment	4	140	35

Source: Created by authors

Table.5: Top 10 publications based on citations received

Rank	Authors	Title	Journal	Citations
1	Barzani <i>et al.</i> (2014)	Optimal fast charging station placing and sizing	Applied Energy	429
2	Sang <i>et al.</i> (2015)	Modelling Electric Vehicle Usage Intentions: An Empirical Study in Malaysia	Journal of Cleaner Production	254
3	Zhang <i>et al.</i> (2011)	Analyzing public awareness and acceptance of alternative fuel vehicles in China: The case of EV	Energy Policy	214
4	Wang <i>et al.</i> (2019)	A global comparison and assessment of incentive policy on electric vehicle promotion	Sustainable Cities and Society	186
5	Zhou <i>et al.</i> (2015)	Plug-in electric vehicle market penetration and incentives: a global review	Mitigation and Adaptation Strategies for Global Change	180
6	Li <i>et al.</i> (2016)	Consumers' evaluation of national new energy vehicle policy in China: An analysis based on a four-paradigm model	Energy Policy	175
7	Li <i>et al.</i> (2019)	An evolutionary analysis of the effect of government policies on electric vehicle diffusion in complex network	Energy Policy	165
8	Wang <i>et al.</i> (2017)	Effectiveness of policy incentives on electric vehicle acceptance in China: A discrete choice analysis	Transportation Research Part A	128
9	Du <i>et al.</i> (2018)	Who buys New Energy Vehicles in China? Assessing social- psychological predictors of purchasing awareness, intention, and Policy	Transportation Research Part F	127
10	Hao <i>et al.</i> (2011)	Fuel conservation and GHG (Greenhouse gas) emissions mitigation scenarios for China's passenger vehicle fleet	Energy	114

Source: Created by authors

Table.6: Tabular representation of journal literature

Category	Number of Journals	Journal Ratio	Loading Volume	Paper Ratio	Average loading density
Core Area	7	6.08%	69	33.33%	9.85
Relevant Area (Zone 1)	40	34.78%	70	33.82%	1.75
Discrete Area (Zone 2)	68	59.13%	68	32.85%	1

Source: Created by authors





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Table.7: Author frequency distribution based on number of publications

Documents written	N. of Authors	Proportion of Authors
1	579	0.8853211
2	57	0.08715596
3	10	0.01529052
4	6	0.00917431
5	1	0.00152905
6	1	0.00152905

Source: Created by authors

Table.8:Collaboration among countries

From	To	Frequency
China	USA	13
China	Hong Kong	4
China	United Kingdom	4
USA	Korea	3
China	France	2
China	Singapore	2
China	Thailand	2
India	Australia	2
Indonesia	Japan	2

Source: Created by authors

Table.9: Prospects for future research

Cluster	Themes	Future Research Directions
1.	Electric vehicle infrastructure and technology	Future studies can examine how government regulations support sustainable transportation systems, battery design developments, and charging options. Research might focus on improving the infrastructure for charging EVs and assessing the long-term effects of government actions (such as incentives and rules) on EV uptake and infrastructure growth.
2.	Sustainability and government policies	Future studies could focus on how integrating circular economy concepts into government regulations can foster the sustainable growth of the electric vehicle (EV) industry. Researchers might investigate the effectiveness of current regulations in minimizing environmental impacts and promoting sustainability throughout the manufacturing, use, and recycling of EVs. Additionally, they could explore ways to enhance regulatory frameworks to better support long-term sustainability in this sector.
3.	Government policy and adoption	Future research could examine the specific barriers, such as cost, charging issues, and infrastructure, that hinder EV adoption. It could also explore how government programs, including subsidies, parking incentives, and fuel tax reductions, can effectively address these barriers. Researchers might also determine the best ways to promote the broad adoption of EVs and evaluate how market





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		incentives and consumer attitudes change due to policy changes.
4.	Purchase intention and barriers to adoption	Future studies should look into the socioeconomic and psychological aspects of EV dependability perceptions, range anxiety, and charging station accessibility that affect consumers' decisions to purchase. Research might look into ways to lessen these obstacles, particularly in important markets like China, which is crucial to the development of EVs worldwide. Research on the effects of shifting consumer preferences on EV adoption can also be quite fruitful.
5.	Environmental impact and transportation	Future research might evaluate the wider environmental advantages of EVs, like lower carbon emissions and better air quality. Researchers may also look into ways that transportation policies, that support renewable energy sources, can improve EVs' environmental advantages. Furthermore, there is a lot of potential for further research into how international rules affect the uptake of EVs and how they contribute to the achievement of global environmental sustainability goals.
6.	China's role in EV development	Future studies may examine China's dominance in the global electric vehicle (EV) industry by exploring its manufacturing capabilities, market dynamics, and policy strategies. Researchers could investigate how China's policies have impacted EV trends worldwide and what lessons other nations can learn from them. Chinese transportation policy changes and their effects on global sustainability and EV innovation could likewise be the subject of studies.

Source: Created by authors

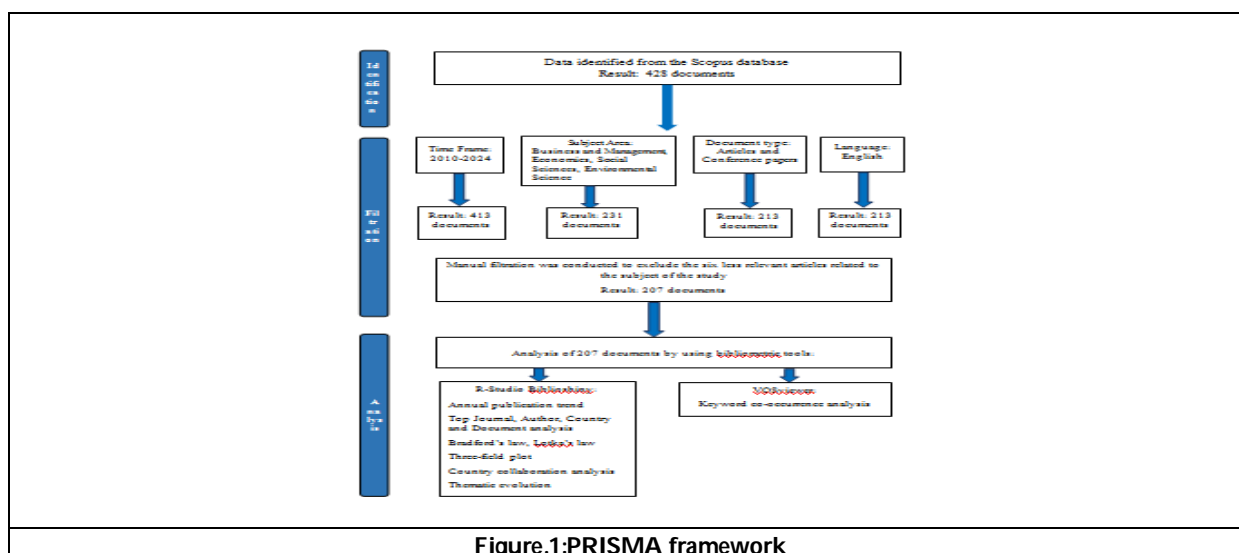


Figure.1:PRISMA framework



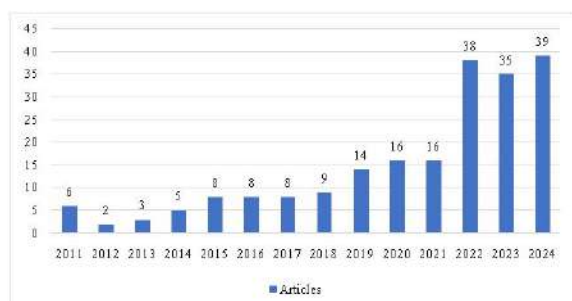


Figure.2:Publication Trend

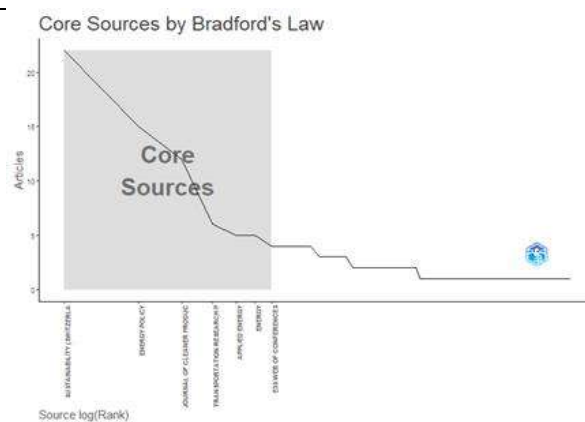


Figure.3:Observed journal publication distribution vs Bradford's law distribution

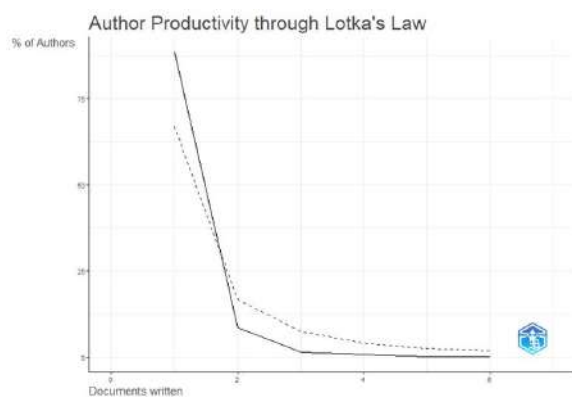


Figure.4: Observed distribution of authorship vs Lotka's law distribution

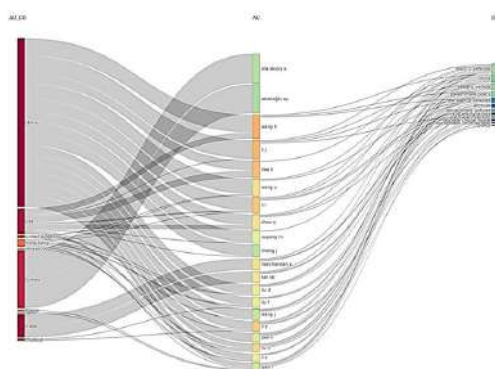


Figure.5:Three-field plot (keywords, authors, and sources)

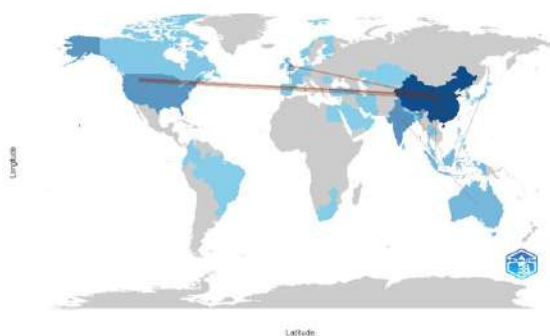


Figure.6:Country collaboration analysis map

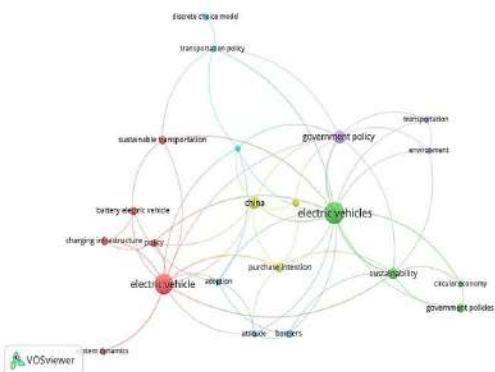
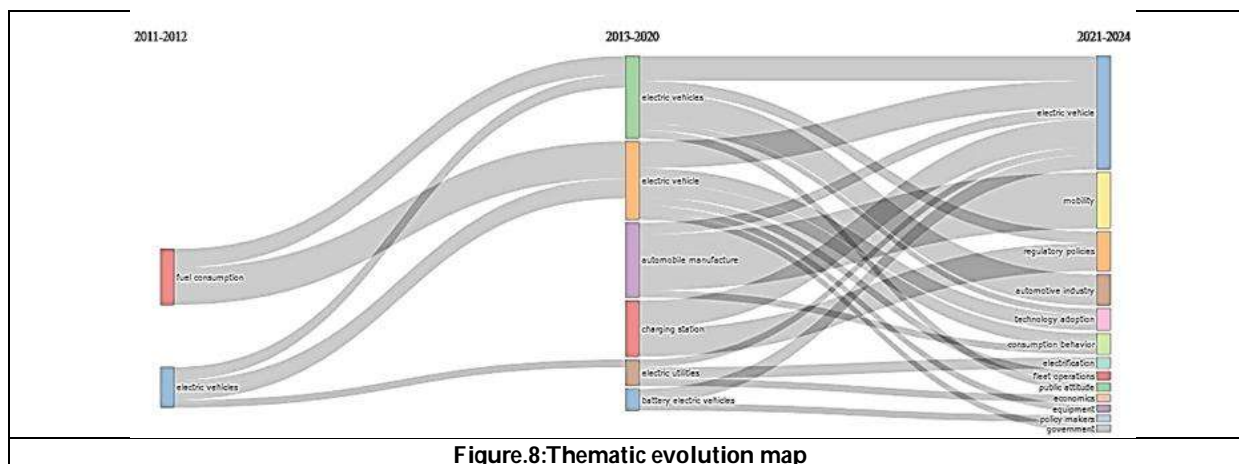


Figure.7:Keyword co-occurrence analysis network





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A Study on Innovations in Indian Agricultural Finance

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ABSTRACT

Financing for agriculture is essential to the sector's growth. In order to sustain the expansion of the agricultural industry, agricultural finance is essential. To improve loan availability and effective utilization, India's rural credit sector has experienced substantial structural modifications. In fact, it is necessary for the production of jobs, food security, and general economic progress. Targets for eradicating hunger, poverty, and inequality must include agriculture and the other value-added agribusinesses and services it provides. Due to the nature of the sector and the amount of private capital available, it has proven to be very challenging to meet the substantial demand for farming investment capital and to provide feasible financial services to rural communities and agriculture, despite numerous efforts by both the private and public sectors. Financial services and formal market systems are inaccessible to a large number of rural families and demographic divisions. These are mostly smallholder farmers. Government policies, on-farm initiatives, and the connections and trade-offs between various hazards must all be considered in an efficient and successful policy approach to managing risks in agriculture. The invention of strategies and goods that can support agricultural financing is made possible by advancements with regard to technology and the organization of agricultural markets. The method of the study is based on the secondary data analysis and evaluation provided by the government of India financial sector lending to agricultural. The objective is to evaluate the existing agricultural financing innovations and to develop the working model for enhancing higher saving, better investments and higher borrowing capacity among small and marginal farmers.

Keywords: Agricultural Finance, Farming Investment, Rural Communities, Sustainable Demand, Financial Services.



**Ananth Kumar and Muralidhar**

INTRODUCTION

Similar to other inputs used in agricultural production, finance plays a crucial role in agriculture. A farmer may only buy and employ technical inputs if he has the necessary funding. However, he always requires outside financing or credit because his personal income is insufficient. Until 1935, the sole source of finance available to farmers was from professional money lenders. When they gave out loans and collected them, they used to apply severe methods and demand unreasonably high interest rates. Farmers were thus severely indebted, and a lot of them continued to be indebted. The RBI of India Act 1934, the District Central Cooperative Banks Act, and the Land Developing Banks Act were passed; as a result, agricultural finance improved and gained momentum. A strong alternative organization was established. Large-scale credit became accessible on easy conditions and with fair interest rates for both loan issuance and repayment. Even while co-operative societies began lending money for agricultural purposes in the 1930s, the industry was not truly taken off until after independence, when appropriate laws and regulations were created. After then, bank lending to agriculture advanced astronomically as a result of branches being opened in rural regions and deposits being drawn in. Price volatility has always existed in the agricultural sector; in fact, price fluctuations for inputs and products are typically more pronounced there than in other industries. Because the industry depends on resources from the earth and climate conditions, risks related to weather fluctuation, natural hazards, pests, and illnesses are especially dangerous.

REVIEW OF LITERATURE

(Teye, E. S., & Quarshie 2021) Mistrust in a failed market leads to institutional behaviour like high interest rates, bureaucratic procedures, loan delays, collateral requests, and large savings deposits, influencing farmers' adoption of enhanced production technology. (Ray 2019) The availability of credit and the number of debt-ridden families have grown significantly, but there's concern due to the sudden rise in outstanding debt and a steady decline in financial institution credit since liberalization. (Vijaykumar et al. 2016) The Kisan Credit Card is a ground-breaking credit delivery tool that provides farmers with quick, flexible funding through a single application process, aiming to provide hassle-free loans for all farmers. (Jainuddin, Hiremath, and Patil 2016) The report indicates a rising national loan disbursement, but a credit disparity exists at the local level and among farmers, particularly for banana and cotton crops, despite increased availability and demand of credit at both financial institutions and farmer groups. (Kumar et al. 2015) The study reveals that various institutional, legislative, and socioeconomic factors significantly impact rural families' access to institutional credit. Factors such as asset ownership, gender, caste affiliation, and education significantly influence these households' ability to obtain loans, resulting in improved incomes. (DR.S.GANDHIMATH and G.Mookambigai 2012) The informal lending sector primarily benefits small farmers, but marginal farmers struggle to obtain sufficient financing in the unofficial credit market, influenced by various interrelated credit contracts. (Kumar 2012) Those who can make a good profit on lending and who are prepared to loan at market rates of interest are considered viable borrowers, minimize rates of lending and deposits to boost the viability of the loan supply, while scale and range economics can minimize transaction costs, implying that raising business volume might make funding available even at lower rates. (M.Govindan 2011) To enhance PACCS's ability to generate revenue, farmers must be granted access to allied and pacific loans.

Objective of the Study

With reference to the performance of agricultural finance in India and its directions towards the improvement in financing the agricultural activities, government has taken many initiatives for the focal development in reachable financial models,

1. To evaluated the policy innovation in agricultural finance for the improvement in the agricultural activities.
2. To analyse and develop the model for enhancement in the agricultural income and savings.



**Ananth Kumar and Muralidhar****Need and Scope of the Study**

With the introduction of capital-intensive agricultural technology, agriculture finance has grown in importance. To increase the productivities of different farm resources, farmers need cash. Low and unpredictable profits are a defining feature of Indian agriculture in general. Both the growth of the agriculture sector and the economy overall depend on credit.

MATERIALS AND METHODOLOGY

The comprehensive implementation and thorough application of the procedure mapping, as well as gathered secondary data published by the Indian government, Ministry of Agriculture and Farmers Welfare, Indian Institute of Management Ahmedabad (IIMA), NABARD, and the Centre for Management in Agriculture for a five-year period between 2018 and 2023, with an eye toward the direction and advancement of science.

RESULTS/ANALYSIS

The development of strategies and goods that can support agricultural financing is made possible by advancements with regard to technology and the organization of agricultural markets. 163.797 million hectares were farmed by 88.883 million agricultural families in India. Floods, droughts, famines, and other natural disasters frequently wreak havoc on farmers' financial situation. Therefore, the type and availability of financing determines whether agricultural production or farm upgrades continue. An evaluation of the following factors is necessary for sustainable agricultural finance: a) risks; b) expenses and distribution channels; c) bankable possibilities; and d) the appropriate product to the right people. Individual farmers can get financing for agricultural innovations through Self Help organizations (SHGs) or Joint Liability Groups (JLGs), which are organizations of individual farmers, as long as banks keep aggregate statistics on this type of financing for agriculture and related activities. Short-term loans for agricultural purposes, sometimes known as crop loans. Horticulture and both conventional and non-traditional plantations will be included. payments up to 10 lakhs made in exchange for the pledge or hypothecation of agricultural products, including warehouse receipts, for a maximum of 12 months, regardless of whether the farmers received crop loans to cultivate the crops. short-term loans provided through partnerships with agri-exporters, sugar mills, and agro-processing facilities. Term loans and working capital are used to finance the investments and working capital needed for agriculture and related industries.

loans to marginal and small-scale farmers so they can buy land for farming. loans to struggling farmers that owe non-institutional lenders money, secured by suitable collateral or collective security. Loans made for pre- and post-harvest tasks carried out by households, groups, or cooperatives of households, including weeding, spraying, harvesting, grading, sorting, processing, and transportation. Funding to maintain a total land development sum of twenty lakh rupees for each borrower. As of December 2022, 3.89 core farmers who were eligible had received Kisan Credit Cards, with a KCC maximum of 4,51,672 core. Over 1.0 lakh (as of October 17, 2022) KCCs were officially authorized for the fisheries sector, and 9.5 lakh (as of November 4, 2022) for the farm animal husbandry sector, after the Government of India's extension of the KCC facility to farmers involved in fishery and animal husbandry in 2018–19. Subsidy-linked loan programs are promoted by the Indian government and provincial governments in an effort to widen agriculture and guarantee small farmers' economic stability. Insurance for crops focuses on confronting issues, agriculture product demand evaluation, technology propelling innovation, plus financing for women is vital in the agriculture industry. Value chain finance is most pertinent to handle these issues. In addition, it's critical to evaluate the difficulties and failures, as well as their underlying causes and appropriate solutions. Scale is a second problem. Using new financial technology and innovations, smallholders, small agro-enterprises, and off-farm rural microenterprises have been successfully reached on several occasions. Nonetheless, a significant constraint impacting several inventive instruments and innovations is the issue of magnitude. Numerous of them are still at the piloting stage or are highly confined, according to the report. A few of the more well-known examples have benefited greatly from donor organizations, but they haven't truly stood through the test for a while or been



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financially self-sufficient. The use of security in conjunction with finance, the value chain strategy for agriculture, and the increasing adoption of mobile apps for small and small families are a few examples. Furthermore, women in farming and product development generally are supported by the expanding acknowledgment of the need of "knowing your client," as well as by improvements in impact evaluations and other related, more comprehensive courses and methods. The study findings and developments in those areas, together with the driving forces of innovation in financing for agriculture and demand, are presented in the next five parts, such as (a) Technical support for farmers and cooperatives resulted in innovations, (2) Institutional reforms that prioritized certain areas of interest, (3) Insurance for crops, (4) Guarantee small farmers' economic stability, and (5) financial technology and innovations.

Modular cycle to enhance higher standards in agricultural sector through injecting credit

Larger-scale plans won't spade the interest of bankers and investors until solid facts and research are available to show how to proceed in order to achieve growth and a successful business model. Until there is compelling data to direct the path ahead for attaining effect with regard to area and target populations, lawmakers will not extend their assistance. Nonetheless, a lot of the novel techniques or ideas have already gained traction. A gap exists between the study's findings and offering structure within the agricultural sector, indicating that while increasing business volume may make funding available and create revenue, growers must be provided the opportunity for allied and Pacific loans. Farmers primarily benefit from this gap, but they battle to obtain enough funding to ensure the sustainability of the loan supply. A theoretical workable model has been developed to ensure higher borrowing capacity in the initial stages with multilevel borrowing for specific innovative and modern agricultural technology only. This can be provided only after educating the need-based farmers concentrating small, medium and marginal farmers.

DISCUSSION

Modular cycle to enhance higher standards in agricultural sector through injecting credit provides for High borrowing for innovative agri-technology leads to higher returns, higher savings, investment in land development and machinery, and high self-suitability, ensuring high borrowing capacity. One of them is the nation's economy's promotion of agriculture, as farmers are becoming more involved and the central government provides banks with a 2% interest subsidy to make agriculture loans more accessible to farmers, particularly small farmers. To provide farmers with operational freedom, NABARD has developed a financial instrument named Kisan Credit Cards (KCC) that makes the supply of cash credit simple and hassle-free. Bank credit is extremely important to the growth of the economy. It should result in fair income distribution and the eradication of poverty in addition to economic progress. The RBI of India, the nation's central bank, developed the concept of directed lending with this goal in mind. Since March 1980, it has been in place through set objectives for lending to key sectors, including agriculture. According to the survey, 11.3 core farmers benefited from government income assistance during the PM KISAN cycle that ran from April to July in 2022–2023. For the last three years, the program has given the farmers in need support totalling over ₹ 2 lakh cores. According to an empirical study conducted by the International Institute for Food Policy Research (IFPRI) and the Indian Council of Agricultural Research (ICAR), the program has specifically assisted small and marginal farmers in meeting their daily consumption, health, education, and other incidental expenses by easing their cash constraints when purchasing agricultural inputs. Assessing how well the government, public sector, and private sector have changed their financial lending practices to support the expansion of agricultural borrowing, savings, and investment. Agricultural lending and investment study that establishes a model's link by evaluating and analysing cumulative data. The new model represented may provide for the benefit of the farmers and agricultural lending institutions.





CONCLUSION

The scope of the study is not limited only to evaluate the agriculture finance inclusions, thus, for extensive agriculture in India is limited. There is little potential for extensive agricultural in India since the study's scope extends beyond evaluating the inclusions in farm funding. Consequently, farming must become more intensive and diverse if agricultural production is to rise. Because intensive agriculture requires a significant amount of cash, there is more room for the study to assess how well the public-private partnership under agricultural finance is working. The distribution of operating assets and operational area is characterized by extreme inequality. Just 2.4% of all farm families with over ten hectares each run more than 23% of the entire operated area, compared with 74.5% of all farm households with a minimum of two acres operating just 26.2% of the total managed area and this has made it possible for the agricultural and related activities sector to considerably contribute to the nation's overall growth, development, and food security.

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Table – 1 Public investment and subsidies in agriculture 2018-19 to 2020-21 (in Core)

Year	Public investment	Subsidy including power	Public Investment as % GVA agri & allied	Subsidies as % GVA agri and allied
2018-19	79473	205678	2.63	6.82
2019-20	72696	220666	2.16	6.57
2020-21*	76852	250195	2.13	6.93

Note: The data on investments and subsidies, except power subsidy, is available from the National Accounts Statistics of MoSPI, and budget documents. The amount spent on power subsidy was computed from the data provided by the Power Finance Corporation.

Table 1 Source: NITI Aayog, National Institution for Transforming India, GOI, New Delhi, July 2023



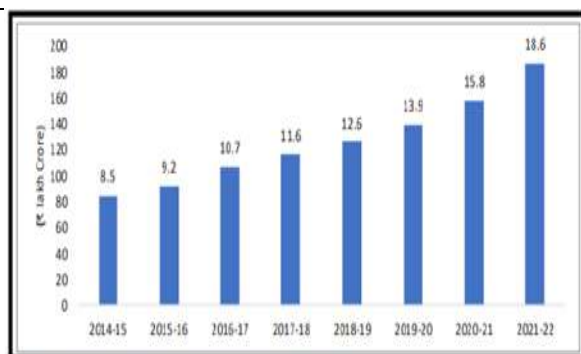
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Figure 1 Source: <https://doi.org/10.21961/2025.894900>

Figure – 1: Graph showing enhanced access to Agricultural credit in India

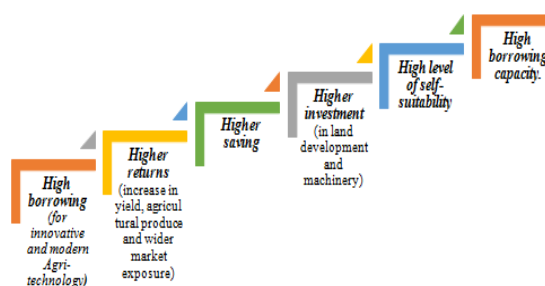


Figure 2 Source: Authors model design

Fig:2





RESEARCH ARTICLE

Pair Mean Cordial Labeling of Pizza Graph, Snail Graph, Sun Graph and Kusudama Flower Graph

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ABSTRACT

Let a graph $G = (V, E)$ be a graph with p vertices and q edges. Define $\kappa = \begin{cases} \frac{p}{2} & p \text{ is even} \\ \frac{p-1}{2} & p \text{ is odd,} \end{cases}$ and $\Gamma = \{\pm 1, \pm 2, \dots, \pm \kappa\}$. Assuming we have a mapping $\chi: V \rightarrow \Gamma$ where, for every even p , we assign a distinct label in Γ to each of the elements of V and for every odd p , we assign a distinct label in Γ to each of the repeat a label for the lone vertex. Then the labeling as described above is considered a pair mean cordial labeling (PMC-labeling) if for every edge uv of G , there is a labeling $\frac{\chi(u)+\chi(v)}{2}$ if $\chi(u) + \chi(v)$ is even and $\frac{\chi(u)+\chi(v)+1}{2}$ if $\chi(u) + \chi(v)$ is odd such that $|\bar{S}_{\chi_1} - \bar{S}_{\chi_1^c}| \leq 1$ where \bar{S}_{χ_1} and $\bar{S}_{\chi_1^c}$ represent the number of edges with a label of 1. A graph G for which there is a pair mean cordial labeling is called a pair mean cordial graph (PMC-graph). This study computes the PMC-labeling of some graphs like pizza graph, snail graph, Kusudama flower graph, $(C_n \times P_2) + K_1$, n -crossed prism graph, half gear graph, sun graph and closed sun graph.

Keywords: pizza graph, sun graph, snail graph, Kusudama flower graph.

2020 AMS Subject Classification: 05C78





INTRODUCTION

This paper contains only finite, simple, and undirected graphs. We refer to [7] for terms and symbols not defined here. Rosa is credited with creating graph labeling [18] and Gallian [6] provides more details on graph labeling. I. Cahit [1] is credited with the idea of cordial labeling and the cordial related labeling idea was examined by a number of writers in [3-5,16,17,20-22]. In [2,8,19,23], we examine the novel kind of graphs and the pair mean cordiality of a few graphs has been studied in [9-15]. In this work, we study pair man cordial labeling of several graphs, including the pizza graph, snail graph, Kusudama flower graph, $(C_n \times P_2) + K_1$, π -crossed prism graph, half gear graph, sun graph and closed sun graph.

PRELIMINARIES

Definition 2.1. [8] The pizza graph P_{Z_n} is a graph that is produced by subdividing wheel graphs W_n in each of their spokes.

Definition 2.2. [23] The snail graph Sl_n is the graph that results from the path P_n joining two parallel edges between v_i and v_{n-i+1} for $i = 1, 2, \dots, \left\lfloor \frac{n}{2} \right\rfloor$.

Definition 2.3. [2] The graph $(C_n \times P_2) + K_1$ resembles a double wheel graph but the vertices of the two wheels are connected pair wise. Another way to think of them is as a prism $C_n \times P_2$, with each vertex connected to an identical point.

Definition 2.4. [2] The graph that is produced from the fan graph F_n by adding a vertex along its path P_n between any two neighboring vertices is known as the half gear graph HG_n .

Definition 2.5. [2] The π -crossed prism graph, R_n of positive even n vertices is the graph that is produced by taking two disjoint cycle graphs C_n and adding edges $v_i v_{2i+1}$ and $v_{i+1} v_{2i}$ for $i = 1, 3, \dots, n-1$.

Definition 2.6. [2] The sun graph S_n is the graph with $2n$ vertices consisting of a center complete graph K_n and an outer ring of n vertices, each of which is connected to both end vertices of the outer ring that is closest to the central core.

Definition 2.7. [2] The closed sun graph \bar{S}_n is the graph that results from $S_n \cup C_n$.

Definition 2.7. [19] Let v_0 represent the apex vertex and v_0, v_1, \dots, v_{2n} be the successive $2n$ rim vertices of wheel graph w_{2n} , $n \geq 3$. Segment spoke edge $v_0 v_{2n-1}$ with vertex w_i and at each w_i , joining two copies of the path of length 2; $P_2^l = v_0, u_{2i-1}, w_i$ and $P_2^r = v_0, u_{2i}, w_i$ for each $i \in [n]$. The resulting graph is known as the Kusudama flower graph KF_n .

MAIN RESULTS

Theorem 3.1. The graph $(C_n \times P_2) + K_1$ is not PMC-graph for every $n \geq 3$.

Proof. Here, $V((C_n \times P_2) + K_1) = \{v_0, v_i, u_i \mid 1 \leq i \leq n\}$ and $E((C_n \times P_2) + K_1) = \{v_0 v_i, v_0 u_i, v_i u_i \mid 1 \leq i \leq n\} \cup \{v_i v_{i+1}, u_i u_{i+1}, v_n v_1, u_n u_1 \mid 1 \leq i \leq n-1\}$ respectively denote the vertex and edge sets of the graph $(C_n \times P_2) + K_1$. So the graph $(C_n \times P_2) + K_1$ holds $5n$ edges and $2n + 1$ vertices. If possible, let χ be a PMC-graph. The possible outcomes are $\chi(u) + \chi(v) = 1$ or $\chi(u) + \chi(v) = 2$ if the edge uv receives the label one. Thereby, $2n - 1$ is the





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greatest number of edges that can be labeled as 1. That's $\bar{S}_{\chi_1} \leq 2n - 1$. Consequently, $\bar{S}_{\chi_1^c} \geq 3n + 1$. Thus, $\bar{S}_{\chi_1^c} - \bar{S}_{\chi_1} \geq 3n + 1 - (2n - 1) = n + 2 \geq 5 > 1$, a contradiction.

Theorem 3.2. The pizza graph Pz_n is a PMC-graph for every $n \geq 3$.

Proof. Here, $V(Pz_n) = \{v_0, u_i, v_i \mid 1 \leq i \leq n\}$ and $(Pz_n) = \{v_0 u_i, u_i v_i \mid 1 \leq i \leq n-1\} \cup \{v_i v_{i+1}, v_n v_1 \mid 1 \leq i \leq n-1\}$ respectively denote the vertex and edge sets of the pizza graph Pz_n . So the pizza graph Pz_n holds $2n + 1$ vertices and $3n$ edges. Let $\chi(v_0) = 1$.

Case (i): For odd n

Let $\chi(v_0) = 1$. At the vertices v_1, v_3, \dots, v_n and v_2, v_4, \dots, v_{n-1} apply the labels $-1, -3, \dots, -n$ and $3, 5, \dots, n$ respectively. Now allot the labels $2, 4, \dots, n-1$ and $-2, -4, \dots, -n+1$ to the corresponding vertices u_1, u_3, \dots, u_{n-2} and u_2, u_4, \dots, u_{n-1} .

Case (ii): For even n

Let $\chi(v_0) = 3$ and $\chi(v_1) = 2$. At the vertices v_2, v_4, \dots, v_{n-2} and v_3, v_5, \dots, v_{n-1} apply the labels $4, 6, \dots, n$ and $-3, -5, \dots, -n$ respectively. Fix the label -1 to u_1 . Consequently, allot the labels $-2, -4, \dots, -n+2$ and $5, 7, \dots, n-1$ to the corresponding vertices u_2, u_4, \dots, u_{n-2} and u_3, u_5, \dots, u_{n-3} . Fix also the label n to u_{n-1} .

χ is a PMC-labeling of the pizza graph Pz_n for every $n \geq 3$ as the accompanying table 1 demonstrates.

Example 3.3. Figure 1 displays a PMC-labeling of the pizza graph Pz_8 .

Theorem 3.4. The Kusudama flower graph KF_n is not PMC-graph for every $n \geq 3$.

Proof. Here the vertex and edge sets of the Kusudama flower graph KF_n respectively denoted by $V(KF_n) = \{v_0, v_i, u_i, w_i, x_i, y_i \mid 1 \leq i \leq n\}$ and $E(KF_n) = \{u_i v_{i+1}, u_n v_1 \mid 1 \leq i \leq n-1\}$

$\cup \{v_0 v_i, v_0 w_i, v_0 x_i, v_0 y_i, w_i u_i, x_i w_i, y_i w_i, v_i u_i \mid 1 \leq i \leq n\}$. So the Kusudama flower graph has $9n$ edges and $5n + 1$ vertices. If possible, let χ be a PMC-graph. The possible outcomes are $\chi(u) + \chi(v) = 1$ or $\chi(u) + \chi(v) = 2$ if the edge uv receives the label one.

Case(i): For odd n

Thereby, $4n - 1$ is the greatest number of edges that can be labeled as 1. That's $\bar{S}_{\chi_1} \leq 4n - 1$. Consequently, $\bar{S}_{\chi_1^c} \geq 5n + 1$. Thus, $\bar{S}_{\chi_1^c} - \bar{S}_{\chi_1} \geq 5n + 1 - (4n - 1) = n + 2 \geq 5 > 1$, a contradiction.

Case(ii): For even n

Thereby, $4n + 1$ is the greatest number of edges that can be labeled as 1.. That's $\bar{S}_{\chi_1} \leq 4n + 1$. Consequently, $\bar{S}_{\chi_1^c} \geq 5n - 1$. Thus, $\bar{S}_{\chi_1^c} - \bar{S}_{\chi_1} \geq 5n - 1 - (4n + 1) = n - 2 \geq 2 > 1$, a contradiction.

Theorem 3.5. The half gear graph Hg_n is a PMC-graph for every $n \geq 3$.

Proof. Here, $V(Hg_n) = \{v_0, u_i, v_i \mid 1 \leq i \leq n \text{ and } 1 \leq j \leq n-1\}$ and

$E(Hg_n) = \{v_0 v_i \mid 1 \leq i \leq n\} \cup \{v_i u_i, u_i v_{i+1} \mid 1 \leq i \leq n-1\}$ respectively denote the vertex and edge sets of the half gear graph Hg_n . So the half gear graph Hg_n holds $2n$ vertices and $3n - 2$ edges. Let $\chi(v_0) = 2$ and $\chi(v_n) = 1$.

Case (i): $n \equiv 0 \pmod{4}$

At the vertices $v_1, v_2, \dots, v_{\frac{3n}{4}}$ and $v_{\frac{3n+4}{4}}, v_{\frac{3n+8}{4}}, \dots, v_{n-1}$ apply the labels $-1, -2, \dots, \frac{-3n}{4}$ and $\frac{-3n-8}{4}, \frac{-3n-12}{4}, \dots, -n$ respectively. Next allot the labels $3, 4, \dots, \frac{3n+4}{4}$ and $\frac{-3n-4}{4}$ to the corresponding vertices $u_1, u_2, \dots, u_{\frac{3n-4}{4}}$ and $u_{\frac{3n}{4}}$. Also allot the labels $\frac{3n+8}{4}, \frac{3n+12}{4}, \dots, n$ to the vertices $u_{\frac{3n+4}{4}}, u_{\frac{3n+8}{4}}, \dots, u_{n-1}$ respectively.





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Case (ii): $n \equiv 1 \pmod{4}$

At the vertices $v_1, v_2, \dots, v_{\frac{3n-3}{4}}$ and $v_{\frac{3n+1}{4}}, v_{\frac{3n+5}{4}}, \dots, v_{n-1}$ apply the labels $-1, -2, \dots, \frac{-3n+3}{4}$ and $\frac{-3n-5}{4}, \frac{-3n-9}{4}, \dots, -n$ respectively. Now allot the labels $3, 4, \dots, \frac{3n+5}{4}$ and $\frac{-3n-1}{4}$ to the corresponding vertices $u_1, u_2, \dots, u_{\frac{3n-3}{4}}$ and $u_{\frac{3n+1}{4}}$. So allot the labels $\frac{3n+9}{4}, \frac{3n+13}{4}, \dots, n$ to the vertices $u_{\frac{3n+5}{4}}, u_{\frac{3n+9}{4}}, \dots, u_{n-1}$ respectively.

Case (iii): $n \equiv 2 \pmod{4}$

At the vertices $v_1, v_2, \dots, v_{\frac{3n-2}{4}}$ and $v_{\frac{3n+2}{4}}, v_{\frac{3n+6}{4}}, \dots, v_{n-1}$ apply the labels $-1, -2, \dots, \frac{-3n+2}{4}$ and $\frac{-3n-6}{4}, \frac{-3n-10}{4}, \dots, -n$ respectively. Subsequently, allot the labels $3, 4, \dots, \frac{3n+6}{4}$ and $\frac{-3n-2}{4}$ to the corresponding vertices $u_1, u_2, \dots, u_{\frac{3n-2}{4}}$ and $u_{\frac{3n+2}{4}}$. Allot the labels $\frac{3n+10}{4}, \frac{3n+14}{4}, \dots, n$ to the vertices $u_{\frac{3n+6}{4}}, u_{\frac{3n+10}{4}}, \dots, u_{n-1}$ respectively.

Case (iv): $n \equiv 3 \pmod{4}$

At the vertices $v_1, v_2, \dots, v_{\frac{3n-1}{4}}$ and $v_{\frac{3n+3}{4}}, v_{\frac{3n+7}{4}}, \dots, v_{n-1}$ apply the labels $-1, -2, \dots, \frac{-3n+1}{4}$ and $\frac{-3n-7}{4}, \frac{-3n-11}{4}, \dots, -n$ respectively. So allot the labels $3, 4, \dots, \frac{3n+3}{4}$ and $\frac{-3n-3}{4}$ to the corresponding vertices $u_1, u_2, \dots, u_{\frac{3n-1}{4}}$ and $u_{\frac{3n+3}{4}}$. Next allot the labels $\frac{3n+7}{4}, \frac{3n+11}{4}, \dots, n$ to the vertices $u_{\frac{3n+3}{4}}, u_{\frac{3n+7}{4}}, \dots, u_{n-1}$ respectively. χ is a PMC-labeling of the half gear graph Hg_n for every $n \geq 3$ as the accompanying table 2 demonstrates.

Example 3.6. Figure 2 displays a PMC-labeling of the half gear graph Hg_5 .**Remark 3.7.** The half gear graph Hg_1 is a PMC-graph but Hg_2 not PMC-graph.**Theorem 3.8.** The n -crossed prism graph Cp_n is a PMC-graph for every even $n \geq 4$.

Proof. Here, the vertex and edge sets of the n -crossed prism graph Cp_n respectively denoted by $V(Cp_n) = \{u_i, v_i \mid 1 \leq i \leq n\}$ and $E(Cp_n) = \{u_i u_{i+1}, v_i v_{i+1}, u_0 u_n, v_0 v_n \mid 1 \leq i \leq n\} \cup \{u_{2i+1} v_{2i}, v_{2i+1} u_{2i} \mid 1 \leq i \leq \frac{n}{2}\}$. So the n -crossed prism graph Cp_n holds $2n$ vertices and $3n$ edges. Let $\chi(v_{n-2}) = 1$, $\chi(v_{n-1}) = \frac{n+4}{2}$ and $\chi(v_n) = \frac{-n-2}{2}$.

Case (i): $n \equiv 0 \pmod{4}$

At the vertices u_1, u_3, \dots, u_{n-1} and u_2, u_4, \dots, u_n apply the labels $2, 3, \dots, \frac{n+2}{2}$ and $-1, -2, \dots, \frac{-n}{2}$ respectively. Next allot the labels $\frac{n+6}{2}, \frac{n+8}{2}, \dots, \frac{3n+8}{4}$ and $\frac{-n-4}{2}, \frac{-n-6}{2}, \dots, \frac{-3n}{4}$ to the corresponding vertices $v_1, v_3, \dots, v_{\frac{n-2}{2}}$ and $v_2, v_4, \dots, v_{\frac{n-4}{2}}$. Now, allot the labels $\frac{-3n-8}{4}, \frac{-3n-4}{4}$ according to the vertices $v_{\frac{n}{2}}, v_{\frac{n+2}{2}}$. So allot the labels $\frac{-3n-12}{4}, \frac{-3n-16}{4}, \dots, -n$ and $\frac{3n+12}{4}, \frac{3n+16}{4}, \dots, n$ to the corresponding vertices $v_{\frac{n+4}{2}}, v_{\frac{n+8}{2}}, \dots, v_{n-4}$ and $v_{\frac{n+6}{2}}, v_{\frac{n+10}{2}}, \dots, v_{n-2}$.

Case (ii): $n \equiv 2 \pmod{4}$

Allot the labels to the vertices $u_i, 1 \leq i \leq n$ as in case (i). Also allot the labels $\frac{n+6}{2}, \frac{n+8}{2}, \dots, \frac{3n+6}{4}$ and $\frac{-n-4}{2}, \frac{-n-6}{2}, \dots, \frac{-3n-2}{4}$ to the corresponding vertices $v_1, v_3, \dots, v_{\frac{n-4}{2}}$ and $v_2, v_4, \dots, v_{\frac{n-2}{2}}$. Allot the label $\frac{-3n-6}{4}$ with $v_{\frac{n}{2}}$. So allot the labels $\frac{-3n-10}{4}, \frac{-3n-14}{4}, \dots, -n$ and $\frac{3n+10}{4}, \frac{3n+14}{4}, \dots, n$ to the corresponding vertices $v_{\frac{n+2}{2}}, v_{\frac{n+6}{2}}, \dots, v_{n-4}$ and $v_{\frac{n+4}{2}}, v_{\frac{n+8}{2}}, \dots, v_{n-2}$.

In all cases, $\bar{S}_{\chi_1} = \frac{3n+2}{2} = \bar{S}_{\chi_1^c}$.

Example 3.9. Figure 3 displays a PMC-labeling of the 8-crossed prism graph Cp_8 .



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Theorem 3.10. The snail graph Sl_n is pair mean cordial for every $n \geq 3$ except for $n = 4$.

Proof. Here the vertex and edge sets of snail graph Sl_n respectively denoted by $V(Sl_n) = \{v_i \mid 1 \leq i \leq n\}$ and $E(Sl_n) = \{v_i v_{i+1}, v_j v_{n-j+1} \mid 1 \leq i \leq n-1 \text{ and } 1 \leq j \leq \frac{n}{2}\}$. So the snail graph Sl_n holds n vertices and $2n-1$ edges, if n is even and $2n-2$ edges, if n is odd.

Case (i): $n = 3$

Allot the labels 1, -1, 1 to the corresponding vertices v_1, v_2, v_3 .

Case (ii): $n = 4$

If possible, let χ be a PMC-graph. The possible outcomes are $\chi(u) + \chi(v) = 1$ or $\chi(u) + \chi(v) = 2$ if the edge uv receives the label one. Thereby, 2 is the greatest number of edges that can be labeled as 1. That's $\overline{S}_{\chi_1} \leq 2$. Consequently, $\overline{S}_{\chi_1^c} \geq 5$. Thus, $\overline{S}_{\chi_1^c} - \overline{S}_{\chi_1} \geq 5 - 2 = 3 > 1$, a contradiction.

Case (i): For odd n

Let $\chi(v_1) = 2$ and $\chi(v_n) = -1$

Now, allot the labels $-2, -3, \dots, \frac{-n}{2}$ and $\frac{n}{2}, \frac{n-2}{2}, \dots, 3$ to the corresponding vertices $v_2, v_3, \dots, v_{\frac{n}{2}}$ and $v_{\frac{n+4}{2}}, v_{\frac{n+6}{2}}, \dots, v_{n-1}$. Allot the label 1 with $v_{\frac{n+2}{2}}$.

Case (ii): For even n

Let $\chi(v_1) = 2$ and $\chi(v_n) = -1$. Next allot the labels $-2, -3, \dots, \frac{-n+1}{2}$ and $\frac{n-1}{2}, \frac{n-3}{2}, \dots, 3$ to the corresponding vertices $v_2, v_3, \dots, v_{\frac{n-1}{2}}$ and $v_{\frac{n+5}{2}}, v_{\frac{n+7}{2}}, \dots, v_{n-1}$. Allot the labels 1, 1 according to $v_{\frac{n+1}{2}}, v_{\frac{n+3}{2}}$.

χ is a PMC-labeling of snail graph Sl_n for every $n \geq 3$ except for $n = 4$ as the accompanying table 3 demonstrates.

Example 3.11. Figure 4 displays a PMC-labeling of the snail graph Sl_7 .

Theorem 3.12. The sun graph S_n is not PMC-graph for every $n \geq 3$.

Proof. Here the vertex and edge sets of the sun graph S_n respectively denoted by $V(S_n) = \{u_i, v_i \mid 1 \leq i \leq n\}$ and $E(S_n) = E(K_n) \cup \{v_i u_i, u_j v_{j+1}, u_n v_1 \mid 1 \leq i \leq n \text{ and } 1 \leq j \leq n-1\}$. So the sun graph holds $2n$ vertices and $\frac{n^2+3n}{2}$ edges. If possible, let χ be a PMC-graph. The possible outcomes are $\chi(u) + \chi(v) = 1$ or $\chi(u) + \chi(v) = 2$ if the edge uv receives the label one. Thereby, $2n-3$ is the greatest number of edges that can be labeled as 1. That's $\overline{S}_{\chi_1} \leq 2n-3$. Consequently, $\overline{S}_{\chi_1^c} \geq \frac{n^2-n+6}{2}$. Thus, $\overline{S}_{\chi_1^c} - \overline{S}_{\chi_1} \geq \frac{n^2-n+6}{2} - (2n-3) = \frac{n^2-5n+12}{2} \geq 3 > 1$, a contradiction.

Theorem 3.13. The closed sun graph \overline{S}_n is not PMC-graph for every $n \geq 3$.

Proof. Here, the vertex and edge sets of the closed sun graph \overline{S}_n denoted by $V(\overline{S}_n) = \{u_i, v_i \mid 1 \leq i \leq n\}$ and $E(\overline{S}_n) = E(K_n) \cup \{v_i u_i, u_j u_{j+1}, u_n u_1, u_j v_{j+1}, u_n v_1 \mid 1 \leq i \leq n \text{ and } 1 \leq j \leq n-1\}$ respectively. So the closed sun graph holds $2n$ vertices and $\frac{n^2+5n}{2}$ edges. If possible, let χ be a PMC-graph. The possible outcomes are $\chi(u) + \chi(v) = 1$ or $\chi(u) + \chi(v) = 2$ if the edge uv receives the label one. Thereby, $2n-3$ is the greatest number of edges that can be labeled as 1. That is $\overline{S}_{\chi_1} \leq 2n-3$. Then $\overline{S}_{\chi_1^c} \geq \frac{n^2+n+6}{2}$. Therefore $\overline{S}_{\chi_1^c} - \overline{S}_{\chi_1} \geq \frac{n^2+n+6}{2} - (2n-3) = \frac{n^2-3n+12}{2} \geq 6 > 1$, a contradiction.





CONCLUSION

A lot of researchers are currently interested in labeled graphs because of their wide range of applications. Here, we talk about PMC-labeling of a few unique graphs. It is an open field of study to get comparable results on different graph families.

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Table 1

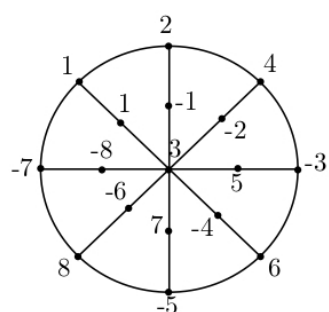
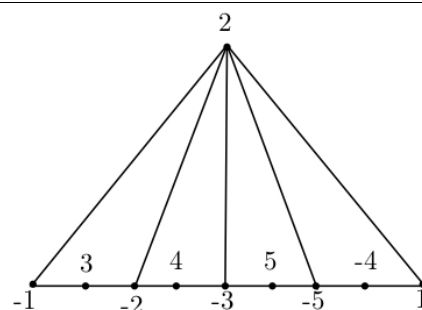
Nature of n	\bar{S}_{x_1}	$\bar{S}_{x_1^c}$
n is odd	$\frac{3n-1}{2}$	$\frac{3n+1}{2}$
n is even	$\frac{3n}{2}$	$\frac{3n}{2}$

Table 2

Nature of n	\bar{S}_{x_1}	$\bar{S}_{x_1^c}$
$n \equiv 0(mod 4)$	$\frac{3n-2}{2}$	$\frac{3n-2}{2}$
$n \equiv 1(mod 4)$	$\frac{3n-3}{2}$	$\frac{3n-1}{2}$
$n \equiv 2(mod 4)$	$\frac{3n-2}{2}$	$\frac{3n-2}{2}$
$n \equiv 3(mod 4)$	$\frac{3n-3}{2}$	$\frac{3n-1}{2}$

Table:3

Nature of n	\bar{S}_{x_1}	$\bar{S}_{x_1^c}$
n is odd	$n-1$	$n-1$
n is even	$n-1$	n

**Figure:1****Figure:2**



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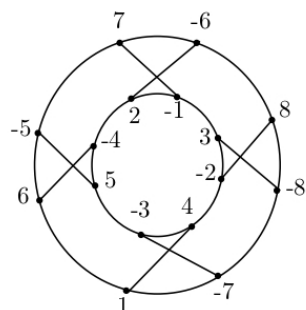


Figure:3





Surface Coated Implants : Enhance Early Osseointegration

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ABSTRACT

The aim of this article to summarises the available literature on assessing different surface coating materials and conditioning techniques available and influence of micro-design of dental implants on their osseointegration. A web-based search of all review articles of Surface coated materials was done using English language databases such as Google Scholar, PubMed, Iran Medex, etc Articles related to the aim of this study were found shown the beneficial effect of surface modification of dental implants, making it new emerging approach for enhancing the success rate of implants and diminish the complications that can be encountered after their placement. Implant's micro-design and surface modifications significantly influence the osseointegration process. Various techniques in implant surface modifications have been proposed, all aimed at improving bone formation around dental implants. Understanding how surface modification of dental implants can impact osseointegration, might help the clinician to maximize the success rate of implants. Surface coated dental implants enhances early osseointegration even in low density bone, might help the clinician to maximize the success rate of dental implants and diminish the complications that can be encounter after their placement.

Keywords: Early bone formation; Implant surface, Surface modifications, Implant coatings & Osseointegration.





INTRODUCTION

Implants have become a popular choice for full mouth rehabilitation, providing support for dental crowns and offering several advantages over conventional dentures for replacing missing teeth [1]. . The importance of dental implants advanced significantly through the groundbreaking research of Professor Per Ingvar Branemark, who focused on studying microcirculation in bone tissue. His research led to the development of the concept of osseointegration, which became the foundation for modern dental implants [2]. For successful implant placement, maintaining alveolar bone thickness, ensuring proper phonetic function, and managing osseointegration are critical factors. Osseointegration refers to the connection between living bone and the surface of a load-bearing implant that is artificially anchored [3]. The quality, distribution, and quantity of bone in the dental implant area play a crucial role in achieving successful osseointegration [4]. Optimal osseointegration relies on several factors, including the characteristics of the implant material, the load applied to the implant, technique used, and quality of bone [5]. . Titanium, often referred to as Ti, is the most commonly used material for dental implants due to its excellent biocompatibility, minimal toxicity, corrosion resistance, and high mechanical strength [6]. . In the past, success rates for dental implants were lower, particularly when failures were assessed based on patients who lost implants. Frequent failures in dental implant therapy were often linked to issues such as instability or misalignment at the implant-abutment interface, which allowed bacterial infiltration along with inflammatory cells to cause bone loss. Some failures were also attributed to infection and inflammation, which affected healing and soft tissue integration. Achieving successful functional and aesthetic outcomes requires careful consideration of the biological principles governing peri-implant soft and hard tissues, as well as the appropriate selection of implant type and placement [7].

Surface Coated Implant

Implant surfaces are treated to enhance biocompatibility, encouraging cells to recognize the material as a natural part of the body rather than a foreign object, thereby reducing the risk of rejection and promoting integration with surrounding tissues [8]. . Various surface modifications have been developed for implants, to enhance the biological response to titanium and reduce the time required for osseointegration (figure1.) These treatments aim to improve surface topography and properties, including techniques such as sandblasting, acid etching, anodization, discrete calcium-phosphate crystal deposition, coatings with biological molecules, and chemical modification [9]. Various materials have been proposed for dental implant coatings, but they do not all offer the same advantages for prostheses. The review will compare traditional titanium (Ti) implants with different implant coatings to assess their properties and effectiveness [10,11,12].

MATERIALS AND METHODS

Article selection

This review evaluates whether the coated implants become the best option for patients in dental implant therapy compared to conventional Ti implants.

Inclusions

Various implant coating materials are compared to the most commonly used titanium (Ti) implants.

Intervention

Researches comparing different coated materials need to be conducted, including those involving the most recent coatings, despite the limited availability of long-term research.

Outcome

Research primarily focuses on achieving biocompatibility and osseointegration. The reviewed article also considers adverse events, such as implant failure after loading and delamination. This review is based on several criteria, including clinical studies conducted both in vitro and in vivo, as well as randomized controlled trials (RCTs). The





search was conducted using PubMed, Wiley, and manual searches, with keywords such as "dental implants," "implant coatings," and "osseointegration."

RESULTS

The micro- design and surface condition of an implant significantly influence the dynamics of osseointegration [13]. The characteristics of the implant surface are directly related to the rate, amount, and quality of bone response. The area of the implant in proximity with bone, the amount of time needed to create direct bone-to-implant contact, and the mechanical link between the implant and the bone are all influenced by the surface features. In other words, chemical and physical surface properties, such as ionic composition, hydrophilicity, and roughness, are key factors in the interaction between the implant and surrounding tissue [14].

Surface modification materials

The hydrophilic properties of treated and hybrid implant surfaces make them more suitable for additional treatments aimed at enhancing their overall characteristics compared to hydrophobic surfaces, such as machined or smooth ones. Implants with hydrophilic surfaces (80%) significantly increase bone-to-implant contact (BIC) during the early healing phase, as they promote greater cell differentiation and aggregation than hydrophobic surfaces (47%) (Figure 2) [8]. A wide range of materials have been utilized as coatings for titanium (Ti) core dental implants, such as Bisphosphonates, bioactive glass, carbon, bone-stimulating agents, bioactive ceramics, fluoride, hydroxyapatite (HA), Calcium phosphate, and titanium nitride (TiN).

Carbon Coated Implants

In addition to being hemo-compatible, histocompatible, biostable, and chemically stable in vitro as well as in vivo, carbon coatings are known to have outstanding chemical characteristics and stability when interacting with etching chemicals. The direct bonding of carbon enhances the adhesion and proliferation of osteoblasts on the surface of nickel-titanium alloys (NiTi) [15].

Bisphosphates

Bisphosphonates have gained research attention in dentistry due to their selective inhibition of osteoclasts and the subsequent improvements in bone quality and osteoblastic activity. However, there are still fewer studies supporting the immersion of titanium (Ti) implants in bisphosphonates compared to other coating materials [16]. Bisphosphonates lead to an increase in the size of osteoclast cells as a compensatory response to their restraining effect. Because the concentration of bisphosphonates affects the bone density surrounding the implant surface, the dosage of anti-resorptive medications needs to be carefully chosen. Tyrosine phosphate is a major target of bisphosphonates since it is essential to the development and operation of osteoclasts [16]. Before starting clinical trials, more study is necessary to fully understand the effects of bisphosphonates as an implant covering.

Hydroxyapatite (HA) Coating

Implanting calcium ions (Ca^{2+}) with a thin hydroxyapatite (HA) coating enhances osteogenic potential while maintaining non-toxicity. This promotes osteoblast activity, leading to improved osseointegration and bioactivity [17]. Hydroxyapatite (HA) coating has gained significant interest due to its ability to enhance osteoconductivity. This coating material offers the advantage of combining the high strength of metals with the excellent bioactivity of the calcium phosphate compound ($\text{Ca}_3(\text{PO}_4)_2$) [18].

Bone Stimulating Factor (BSF)

Research indicates that BSF significantly enhances the osseointegration process. Applying BSF, such as bone morphogenetic protein (BMP), as a coating can improve bone density around the implant and enhance the biocompatibility of the prosthesis [19]. BSF is a promising and innovative coating material, as it not only enhances healing after surgical implant placement but also promotes improved osseointegration.





Bioactive Glass and Ceramics

The glassy qualities of bioactive glass, which improve osseointegration and lessen corrosion in body fluids, make it novel and helpful for dental implants. However, its limited use in load-bearing areas raises concerns about durability. In vitro studies have demonstrated that bioactive glass meets both requirements, even after several months of load resistance testing [18]. More over 60% of the weight in silica can cause delamination, and cracking. This problem can be solved by partially replacing calcium oxide (CaO) in bioglass compositions with magnesium oxide (MgO), sodium oxide (Na₂O), and potassium oxide (K₂O). This adjustment helps balance thermal expansion between the coating and titanium-based alloys [19].

Osseo Speed (Dentsply)

A surface structure altered by fluorine nanoparticles is sold to encourage the development of bones early. Monjo *et al.* could not find any difference in biocompatibility between fluorine-coated implants and TiOblast (Dentsply). However, the fluorine coating induces more branched cellular morphology at the implant site, enhancing osteoblast differentiation [20].

Nitride Compounds

The TiN layer's thickness and the surface coating can be changed to improve osseointegration by causing a neurological reaction associated with the coating's nitrogen. These coatings demonstrate good blood compatibility, as they show protein absorption and platelet retention comparable to those of medical elastomers. Additionally, TiN coatings help regulate the formation of TiO layers, promoting strong bonding [21].

Implant Surface Modification Techniques

Numerous micro rough titanium surfaces have been created over the years to improve bone-to-implant contact (BIC) and overcome the shortcomings of machined surfaces, also referred to as "turned" or "smooth." These rough surfaces can be created using various modification techniques, including both additive and subtractive methods (Figure 3).

Additive Processes

Titanium plasma-sprayed (TPS) surfaces Originally, this method was created for medical implants. After implanting a titanium hybrid powder onto the implants via plasma spraying, the implants were put to the test by being inserted into sheep. Titanium is heated in an ionic component plasma stream during the plasma coating process, producing an average coating roughness of 7mm. This roughness enhances the surface area of the implant, which improves the interaction between bone and connective tissue with dental implants featuring a Titanium Plasma Spraying (TPS) surface. Schroeder *et al.* conducted a study using a monkey model, which revealed that the implants were successfully ankylosed to the surrounding bone and maintained stability even under loading conditions for up to 2 years [22].

Hydroxyapatite and Other Calcium Phosphate Surface Coating

These materials are primarily composed of hydroxyapatite (HA) and are released into the peri-implant region following implant placement [23]. Calcium phosphate materials offer two main advantages: they accelerate early healing and effectively bond to bone. This accelerated healing is attributed to their ability to readily adsorb proteins onto their surfaces [24]. Enhanced fibrinogen binding can lead to increased platelet adhesion and activation. Additionally, fibrin binding to the implant surface acts as a bridge between osteogenic cells and the implant, resulting in superior osseointegration in vivo [24]. Resorbable blast media (RBM), which involves blasting the implant surface with coarse calcium phosphate, was also investigated in multiple studies, showing significantly higher values of BIC% was noted with RBM implants when compared with machined implants [25]. Enhanced activation and adhesion of platelets can result from enhanced fibrinogen binding. Furthermore, fibrin that binds to the implant surface creates a bridge that connects osteogenic cells to the implant, improving osseointegration in vivo.



**Plasma Electrolytic Oxidation (Coating and Doping)**

Beta-Tech Medicine LLC (Skolkovo, Russia) has developed a promising domestic method for dental implant surface treatment. This technique ensures a high level of implant purity and enhances osseointegration. It involves forming a hard oxide-ceramic coating with a porous structure that chemically adheres to the titanium base. The coating comprises 41.66% titanium (by atomic composition) from the implant material itself, ensuring excellent surface attachment. Additionally, the implants are doped with calcium and phosphorus atoms to more closely mimic the natural bone tissue structure. During the treatment process, these doping ions are introduced into the coating from the oxidizing electrolyte and are distributed uniformly throughout the coating [26].

Subtractive Processes

Grit-blasted surfaces are created by texturing metal surfaces with a pressurized spray to increase surface irregularity. This process uses blasting agents such as alumina (Al_2O_3) and TiO_2 , resulting in a macroscopic surface texture that resembles sandpaper. Both the pressure and the type of particles used can influence the outcome of the sandblasting process [27]. Cell adhesion mechanisms can be affected by sandblasting and acid etching because the osteoblast-like cells that stick to these surfaces have uneven shape and many pseudopodia. Furthermore, it has been demonstrated that implants with chemically altered sandblasted and acid-etched surfaces recover more quickly. For example, early loading at 21 days resulted in a 100% survival and success rate over a 3-year observation period [28].

Acid-Etched Surfaces

Acids such as HCl , H_2SO_4 , and HF can be used as chemical agents for etching titanium implants. This process removes a small amount of material, creating microscopic pits on the implant surface to enhance surface roughness and improve osseointegration. A group of researchers demonstrated that dual etching of titanium can enhance early osseointegration. After 36 months of healing, the success rate for the dual-acid-etched (DAE) implants was 95%, compared to 86.7% for the machined implants [29].

Electro Polishing

All titanium implants develop an oxide coating over time, but oxidised implants have a thicker layer since they were anodized in a galvanic cell containing the right electrolyte. This process involves passing a current through the implant with phosphoric acid as the electrolyte, which forms the surface oxide and enhances the implant's biological performance [30].

Mechanical Polishing

Machined implants exhibit characteristic grooves resulting from the manufacturing tools used during production. Machined implants are produced through turning, milling, or polishing processes, resulting in a minimally rough surface with a surface area roughness (S_a) value between 0.3 and 1.0 μm . The surface morphology is influenced by factors such as the manufacturing tools, implant material, lubricants, and the machining speed [31].

Laser Surface Micro Texturing

It is a non-contact treatment method where the implant surface remains uncontaminated by blasting media. Laser etching vaporizes the substrate material, creating a crater on the surface. This method offers greater precision in controlling the micro-topography of the implant surface, thereby enhancing its biocompatibility [32]. In comparison to control-machined implants, the effects of laser micro-texturing on bone attachment were assessed in a 3-year follow-up research. The results showed better bone preservation, with 0.46 mm of crestal bone loss observed at the 3-year mark and no bone loss up to the first thread [33].

Biological Coatings**Growth factors Coatings**

Growth factors such as bone morphogenetic proteins, transforming growth factor- $\beta 1$ (TGF- $\beta 1$), platelet-derived growth factor, and insulin-like growth factors 1 and 2 are frequently studied for surface coatings. Notably, TGF- $\beta 1$ has been shown to stimulate and enhance bone growth by 59% [34]. Implants coated with bone-enhancing materials



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provide significant healing potential following surgical placement and improve osseointegration in the peri-implant region [35].

Peptides

Adhesion molecules like Collagen I and peptide coatings substantially improve bone-to-implant contact (BIC) by facilitating enhanced regeneration. BSF is a promising and innovative coating that not only supports healing after surgical implant placement but also enhances osseointegration in the peri-implant region [36].

DISCUSSION

Various materials have been proposed for implant coatings, resulting in a range of surface characteristics. These characteristics are achieved through methods such as coatings, blasting, acid etching, laser treatment, or combinations of these techniques. Rough implant surfaces have been demonstrated to offer superior properties compared to traditional machined surfaces. While an ideal implant surface characteristic has not yet been established, advancements in micro-design and surface modifications have significantly enhanced osseointegration. These advancements may, in turn, increase dental implant success rates and lower related problems. In order to improve osseointegration and increase bone-to-implant contact, researchers are constantly looking for the ideal implant surface conditions. Still, a lot of clinical trials are needed to establish a strong body of evidence and guarantee long-term effectiveness.

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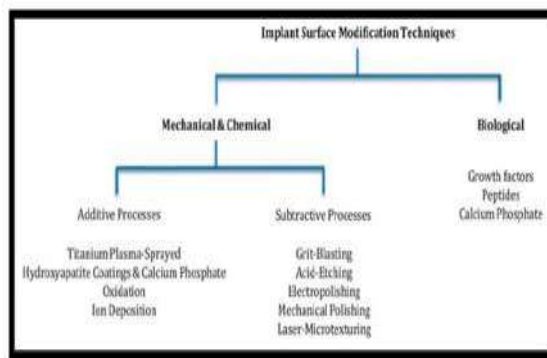
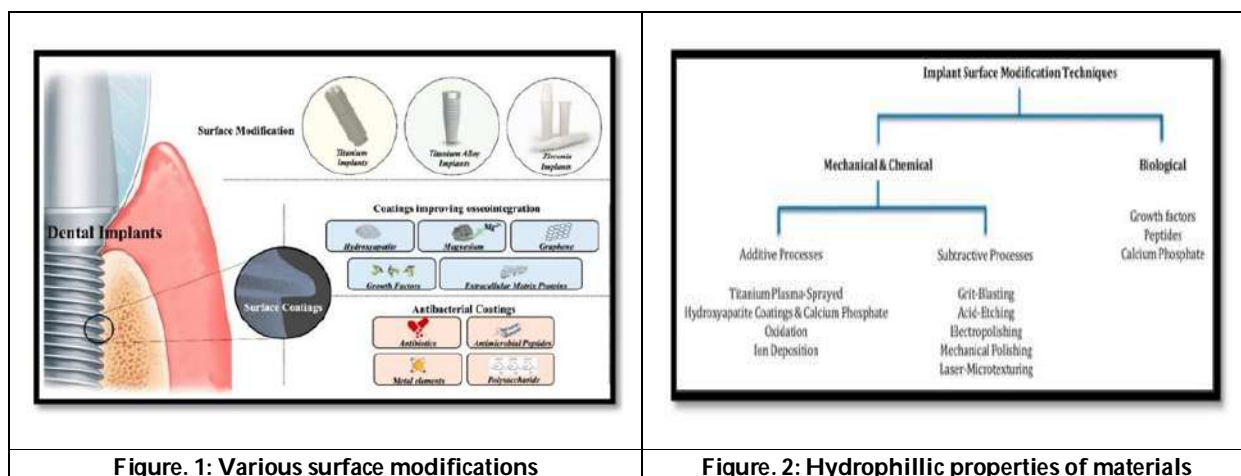
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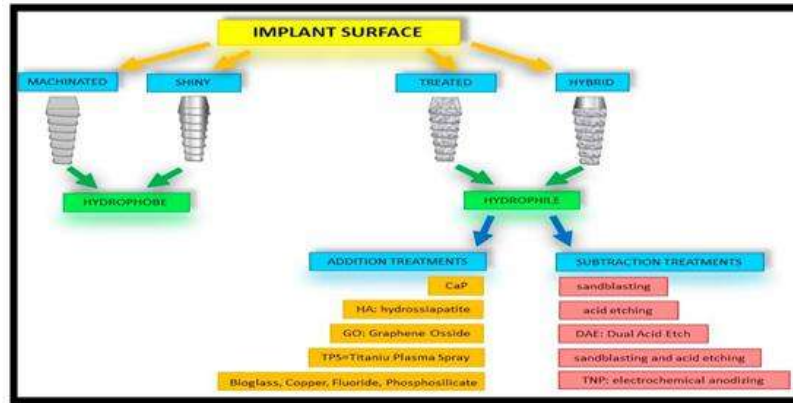


Figure. 3: Surface modification techniques





Artificial Intelligence (AI) and its Impact on Online Shopping Consumer Behaviour with Special Reference to Bengaluru

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ABSTRACT

Artificial Intelligence (AI) has the potential to drive productivity and economic growth by enhancing decision-making quality and efficiency. It also plays a crucial role in fostering innovation, leading to the emergence of new services, markets, and even entire industries. However, AI also presents challenges that could negatively impact businesses and society. Despite teleological theories suggesting that symbolic AI is an inevitable outcome of centuries of efforts to formalize human intelligence, AI remains an evolving field with both opportunities and risks. AI technologies rely on machine learning algorithms, which are only as effective as the data they are trained on. Since humans determine the data used to train AI systems, the risk of machine learning bias is inevitable and must be continuously monitored. In the retail sector, digital transformation is reshaping the competitive landscape, distinguishing successful businesses from those that struggle to adapt. AI offers numerous advantages for retailers, from enhancing operational efficiency to revolutionizing customer interactions. In the future, many advanced companies are expected to rely on AI-powered digital assistants, reducing the need for human intervention. This study explores how AI influences online shopping behaviour, addressing its limitations, outcomes, and recommendations. It examines how AI functions within digital purchasing transactions and its impact on consumer decision-making. Understanding consumer behaviour in digital commerce is essential, as AI-driven enhancements have the potential to transform the online shopping experience. The research aims to analyse the effects of AI-driven technologies on consumer choices, particularly for individuals purchasing practical goods through online platforms. The study is conducted in Bengaluru, targeting individuals aged 20 and above who actively engage in online shopping. A total of 103 respondents, comprising both male and female participants, were surveyed. The study utilizes both primary and secondary data to assess consumer awareness and the influence of AI on online shopping behaviour. A random sampling method was employed, and statistical tools such as SPSS and Excel were used for





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data analysis. Various research techniques, including mean and Pearson Correlation were applied. The study adopts both analytical and descriptive research approaches to provide comprehensive insights.

Keywords: Artificial Intelligence, AI-Powered Support, COVID-19, Digital Marketing, E-commerce, Online Shopping.

INTRODUCTION

The rapid advancement of Artificial Intelligence (AI) has transformed industries, with e-commerce being one of the most affected sectors. AI technologies are reshaping online shopping by offering personalized recommendations, automating services, optimizing supply chains, and enhancing customer engagement. These innovations have improved business efficiency and reshaped consumer behaviour, making shopping more intuitive and data-driven. In India, particularly in urban centers like Bengaluru, online shopping has surged due to increased internet and smartphone use. As a tech hub, Bengaluru is home to tech-savvy consumers who embrace AI tools like voice assistants, chatbots, and predictive analytics, which influence purchasing decisions and improve user satisfaction through personalized suggestions and dynamic pricing. AI algorithms analyse consumer data, enabling tailored shopping experiences and enhancing customer support through NLP-powered chatbots. Additionally, AI-driven fraud detection boosts trust, while innovations like AR-enabled try-ons and demand forecasting enhance the overall shopping experience. Bengaluru's status as a tech-driven city makes it an ideal case for examining the impact of AI on online shopping behaviour. This study explores how AI shapes consumer decision-making, shopping preferences, and brand interactions, while assessing the challenges and opportunities for both businesses and consumers. As AI evolves, its role in e-commerce will expand, offering new possibilities for personalization, automation, and efficiency.

LITERATURE REVIEW

Bhagat, R. (2022): "The Role of AI in Online Shopping: Factors Influencing Practical Application and Consumer Behaviour." *Journal of E-commerce and Digital Marketing*, vol. 12, no. 1, 2022, pp. 23-35. This study explores the role of AI in online shopping, focusing on factors that influence its practical application and its impact on consumer behaviour. By using a technological model, the research examines elements affecting consumers' likelihood to purchase online. The findings suggest that AI helps businesses understand customer needs and enhances digital commerce by moderating purchasing decisions, thus boosting customers' propensity to buy and marketers' ability to increase online buying intent. **Rahman, M. A. et al. (2021):** "The Growing Popularity of Online Shopping in Bangladesh: Consumer Preferences and Challenges." *Journal of Digital Commerce Studies*, vol. 8, no. 3, 2021, pp. 112-125. The study highlights the growing popularity of online shopping in Bangladesh, where consumers prefer its convenience and product variety but dislike the inability to inspect products before purchasing. Social media influences store discovery, with clothing and accessories being the most common purchases. Despite the preference for cash on delivery, concerns over payment security and dissatisfaction hinder broader adoption. **Arul Rajan, K. (2020):** "Hedonic and Utilitarian Motivations in Online Shopping: An Analysis of Consumer Behaviour in Coimbatore." *International Journal of Consumer Behaviour*, vol. 15, no. 4, 2020, pp. 78-92. This study analyses how hedonic and utilitarian motivations affect online shopping behaviour in Coimbatore. It explores key drivers like social media, technology, and shopping convenience. The study categorizes hedonic motivations into six subtypes and utilitarian into two, emphasizing the Impulse vs. Rational buying dichotomy. Online platforms have reshaped decision-making, reducing deliberation time compared to traditional shopping. **Kumar, V. et al. (2019):** "AI's Role in Personalized Engagement Marketing." *Journal of Marketing Technology*, vol. 34, no. 2, 2019, pp. 45-58. This research discusses AI's role in personalized engagement marketing, helping businesses provide tailored products and services. It explores how AI curates information to meet customer needs and examines its potential impact on marketing and customer service in both developed and developing countries. **Kumar, S. & Kumar, M. (2019):** "Customer Churn Prediction Using AI in Competitive Markets." *Journal of Marketing Analytics*, vol. 21, no. 2,



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2019, pp. 45-60. This study focuses on customer churn in competitive markets, highlighting how AI helps predict and address attrition. Using telecommunications data and Artificial Neural Networks, it identifies key churn drivers and optimizes solutions through testing various activation functions. **Brill, T. M. et al. (2019):** "The Rise of Digital Assistants: Enhancing Customer Interactions and Business Operations with AI." *Journal of Business Technology*, vol. 18, no. 3, 2019, pp. 123-135. The study projects a significant increase in digital assistant users and examines how AI-powered assistants, like Siri and Alexa, streamline operations and enhance customer interactions. Using PLS-SEM analysis, the research highlights customer satisfaction and the effectiveness of these assistants in improving business operations and marketing strategies. **Pandey, A. & Parmar, J. (2019):** "Factors Influencing Online Shopping Behaviour in Kanpur, India." *International Journal of E-commerce Research*, vol. 10, no. 4, 2019, pp. 98-110. The study investigates factors influencing online shopping behaviour in Kanpur, India. It identifies key determinants like demographics, social influences, online experience, and payment options. While limited in sample size, the study provides insights for e-commerce marketing strategies and suggests areas for future research. **Maheswari, K. & Priya, P. P. A. (2017):** "The Impact of Personality and Character Traits on Online Purchasing Habits: A Data Mining Approach." *Journal of Consumer Behaviour and Analytics*, vol. 6, no. 2, 2017, pp. 215-228. This research examines the impact of personality and character traits on purchasing habits. Using data mining techniques, it classifies customers based on their shopping behaviour. The study demonstrates the effectiveness of SVM algorithms in analysing consumer behaviour based on online sales and inventory data.

RESEARCH GAP

Despite extensive research on AI's role in business efficiency and innovation, there is limited understanding of its impact on consumer behaviour in online shopping. Existing studies often overlook AI's influence on decision-making in digital commerce and its potential biases. Additionally, the effect of AI-powered assistants on purchasing decisions for practical goods is underexplored. This study addresses these gaps by analysing AI's role in shaping consumer choices in Bengaluru. The findings will offer valuable insights for retailers to optimize AI strategies and enhance customer engagement.

NEED OF THE STUDY

This study addresses the gap in understanding AI's influence on consumer behavior in online shopping, particularly post-COVID-19. It explores how AI-driven insights help businesses optimize product placement and adapt to changing consumer preferences. The research provides valuable guidance for e-retailers in targeting both urban and rural customers effectively.

OBJECTIVES

1. To examine consumer awareness of AI, with online shopping as the independent variable.
2. To examine the influence of AI on consumer buying behaviour in online shopping.
3. To assess AI's impact on purchase decisions across different demographic characteristics.

Hypothesis

H₀ (Null Hypothesis): AI-driven features in online shopping do not significantly impact consumer behaviour, perception, or satisfaction.

H₁ (Alternative Hypothesis): AI-driven features in online shopping significantly influence consumer behaviour, perception, and satisfaction.

RESEARCH METHODOLOGY

Sampling Technique is the term used to describe the method utilized to collect the samples. Every element does have an equal likelihood of being selected as a sample piece. It is employed when there is no prior knowledge of the target demographic. Males and females were selected using a random sampling technique for the study. **A primary data**



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source is an original data source that was acquired directly for a specific study purpose or activity. Primary data had been collected from chosen respondents using questionnaires. **Secondary data** had been sourced from “books, journals, and articles from various websites, reports, magazines, and newspapers.” The secondary and primary data were used for data collection, which had been developed to capture the awareness and impact of artificial intelligence on consumer behaviour in online shopping.

STATISTICAL TOOLS used in this study are excel and SPSS.

DATA ANALYSIS - DEMOGRAPHICS OF THE RESPONDENTS

The study employs a data-driven approach, utilizing primary and secondary data sources to assess AI's impact on consumer behaviour. Primary data is collected through surveys and interviews with online shoppers in Bengaluru, while secondary data includes reports from e-commerce platforms, AI market trends, and academic literature. Statistical tools being used in this study. The majority of respondents are male (68%), while female respondents make up 32%. This suggests that the survey sample is male-dominated, which might influence findings if gender plays a role in the study's focus. Most respondents fall within the 18-25 age group (94%). Only a small percentage belong to 26-35 (3%), 36-45 (2%), and 46+ (1%) categories. This indicates that the study primarily captures younger individuals, potentially students or early-career professionals. The vast majority are undergraduates (94%), with a few postgraduates (3%) and doctorate holders (2%). Only 1% have a high school education, confirming that the sample consists mostly of highly educated individuals. A significant portion of respondents are students (87%). A small percentage are self-employed (4%), private sector employees (6%), and government employees (3%). This aligns with the age and education data, reinforcing that the sample is mainly composed of young students. 50% earn less than 20,000, which aligns with the student-dominated sample. 25% earn between 20,000-50,000, 17% between 50,000-100,000, and 8% earn more than 100,000. This indicates a majority with lower disposable income, likely affecting their purchasing behaviours. 53% shop rarely (once a month or less), while 36% shop occasionally (2-3 times a month). Only 8% shop frequently (weekly), and 3% shop very frequently (multiple times a week). This suggests that most respondents are not frequent online shoppers, which could be influenced by their income levels and student status. (1= Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

Detailed Interpretation of Each Correlation Table

The correlation tables provide statistical relationships between different variables. Below is the interpretation of each table:

Interpretation

- There is no significant correlation between gender and any of the AI-related variables ($p > 0.05$ in all cases).
- This suggests that gender does not influence AI awareness, impact on behaviour, perception, or satisfaction in online shopping.

Interpretation

- Age has no significant relationship with AI-related variables ($p > 0.05$).
- This means that younger and older individuals have similar AI awareness, perception, and satisfaction levels in online shopping.

Interpretation

- Education does not significantly correlate with AI-related variables ($p > 0.05$).
- The weak negative correlation with perception (-0.167) suggests that higher education levels may slightly reduce trust in AI personalization and security, but this is not statistically significant.

Interpretation

- Occupation does not significantly influence AI awareness, impact, perception, or satisfaction ($p > 0.05$).



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- The weak negative correlation between occupation and perception (-0.160) indicates that certain job categories might slightly distrust AI personalization, but this is not statistically significant.

Interpretation

- Income has no significant impact on AI-related variables ($p > 0.05$).
- This means AI awareness, perception, and satisfaction are not influenced by income levels.

Interpretation

- Strong correlation between awareness (QA) and satisfaction (QS) ($r = 0.688$, $p < 0.001$): Consumers who are aware of AI in online shopping tend to be more satisfied.
- Awareness also significantly impacts shopping behaviour (QI) ($r = 0.588$, $p < 0.001$): AI-aware users are more likely to be influenced by AI-driven recommendations.
- Moderate correlation with perception (QP) ($r = 0.381$, $p < 0.001$): Awareness influences how AI personalization and security are perceived.

Interpretation

- Strong correlation with satisfaction (QS) ($r = 0.742$, $p < 0.001$): If AI influences shopping behaviour, the customer is more likely to be satisfied.
- Moderate correlation with perception (QP) ($r = 0.512$, $p < 0.001$): AI's impact on behaviour affects how consumers perceive AI security and personalization.

Interpretation

- Moderate positive correlation ($r = 0.517$, $p < 0.001$): Consumers who trust AI-driven personalization and security tend to have higher satisfaction levels.

Interpretation

- Shopping frequency significantly correlates with AI awareness ($r = 0.282$, $p = 0.004$): Consumers who shop online frequently are more aware of AI in online shopping.
- No significant relationship with AI impact, perception, or satisfaction ($p > 0.05$).

Final Interpretation with Hypothesis Testing**Summary of Findings from Correlation Analysis**

1. **AI Awareness (QA) significantly influences**
 - a. Shopping behaviour (QI) ($r = 0.588$, $p < 0.001$)
 - b. Perception of AI (QP) ($r = 0.381$, $p < 0.001$)
 - c. Customer Satisfaction (QS) ($r = 0.688$, $p < 0.001$)
2. **AI Impact on Shopping Behaviour (QI) strongly influences:**
 - a. Customer Satisfaction (QS) ($r = 0.742$, $p < 0.001$)
 - b. Perception of AI (QP) ($r = 0.512$, $p < 0.001$)
3. **AI Perception (QP) has a moderate effect on Satisfaction (QS) ($r = 0.517$, $p < 0.001$).**
4. **Demographic Factors (Gender, Age, Education, Occupation, Income):**
 - a. No significant correlation with AI variables ($p > 0.05$).
5. **Shopping Frequency:**
 - a. **Positively correlates with AI awareness ($r = 0.282$, $p = 0.004$)**
 - b. No significant impact on behaviour, perception, or satisfaction ($p > 0.05$).

Hypothesis Testing

- **Null Hypothesis (H_0):** AI-driven features in online shopping do not significantly impact consumer behaviour, perception, or satisfaction.





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- **Alternative Hypothesis (H₁):** AI-driven features in online shopping significantly influence consumer behaviour, perception, and satisfaction.

Decision

Since AI awareness, shopping behaviour, perception, and satisfaction show **statistically significant correlations ($p < 0.001$ in most cases)**, the **null hypothesis (H₀) is rejected** and the **alternative hypothesis (H₁) is accepted**.

CONCLUSION

AI awareness (QA) plays a crucial role in shaping consumer behaviour (QI), perception (QP), and satisfaction (QS), with shopping behaviour (QI) demonstrating the strongest correlation with satisfaction (QS) ($r = 0.742$, $p < 0.001$). This suggests that consumers who engage more actively in AI-driven shopping experiences tend to report higher satisfaction levels. Interestingly, demographic factors such as gender, age, education, occupation, and income do not significantly impact AI awareness, perception, or satisfaction, indicating that AI's influence is largely independent of traditional demographic distinctions. Given the substantial effect of AI-driven features on consumer behaviour, perception, and satisfaction, the null hypothesis (H₀) is rejected, and the alternative hypothesis (H₁) is accepted. This confirms that AI technologies play a pivotal role in shaping consumer experiences. AI-driven recommendations, chatbots, and security features enhance online shopping by providing personalized interactions, streamlining decision-making processes, and increasing consumer trust. Consumers who are more aware of AI and its functionalities tend to exhibit higher satisfaction, reinforcing the importance of AI-driven innovations in e-commerce. Despite the significant role of AI in improving consumer experiences, demographic factors do not appear to affect AI adoption in online shopping. This suggests that AI technologies are widely accepted across various consumer segments, highlighting their universal appeal and effectiveness. As AI continues to evolve, its ability to enhance shopping behaviour, perception, and satisfaction will likely strengthen, further solidifying its role in the digital commerce landscape.

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Table:1

GENDER					
		FREQUENCY	PERCENTAGE	VALID PERCENTAGE	CUMMULATIVE PERCENTAGE
VALID	MALE	70	68	68	68
	FEMALE	33	32	32	100
	TOTAL	103	100	100	

Table:2

AGE					
		FREQUENCY	PERCENTAGE	VALID PERCENTAGE	CUMMULATIVE PERCENTAGE
VALID	18-25	97	94	94	94
	26-35	03	03	03	97
	36-45	02	02	02	99
	46 and above	01	01	01	100
	TOTAL	103	100	100	

Table:3

EDUCATION LEVEL					
		FREQUENCY	PERCENTAGE	VALID PERCENTAGE	CUMMULATIVE PERCENTAGE
VALID	HIGH SCHOOL	01	1	1	1
	UNDERGRADUATE	97	94	94	95
	POST GRADUATE	03	03	03	98
	DOCTORATE	02	02	02	100
	TOTAL	103	100	100	

Table:4

OCCUPATION					
		FREQUENCY	PERCENTAGE	VALID PERCENTAGE	CUMMULATIVE PERCENTAGE
VALID	STUDENT	90	87	87	87
	SELF EMPLOYED	04	04	04	91
	PRIVATE SECTOR EMPLOYEE	06	06	06	97
	GOVERNMENT	03	03	03	100
	TOTAL	103	100	100	



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Table:6

MONTHLY INCOME					
		FREQUENCY	PERCENTAGE	VALID PERCENTAGE	CUMMULATIVE PERCENTAGE
VALID	LESS THAN 20,00	51	50	50	50
	20,000-50,000	26	25	25	75
	50,000-100,000	18	17	17	92
	MORE THAN 1,00,000	08	8	8	100
	TOTAL	103	100	100	

Table:7

FREQUENTLY SHOPPING ONLINE					
		FREQUENCY	PERCENTAGE	VALID PERCENTAGE	CUMMULATIVE PERCENTAGE
VALID	Rarely (once a month or less)	55	53	53	53
	Occasionally (2-3 times a month)	37	36	36	89
	Frequently (once a week)	08	08	08	97
	Very frequently (multiple times a week)	03	03	03	100
	TOTAL	103	100	100	

Table:8

Variables	Q	Items	Agreement Scale				
			SD	D	U	A	SA
			1	2	3	4	5
Awareness and Usage of AI in Online Shopping (Awareness = A)	Q	I am aware that AI is used in online shopping platforms.	20	44	26	5	8
	QA	I have noticed AI-based recommendations while shopping online (e.g., personalized product suggestions).	16	48	33	04	02
	QA	AI chatbots enhance my online shopping experience by providing quick support.	09	50	33	07	04
	QA	AI-driven price comparison tools help me make better purchasing decisions.	11	46	31	11	04
Impact of AI on Online Shopping Behaviour. (Impact=I)	QI	AI-generated product recommendations influence my purchase decisions.	05	48	31	13	06
	QI	AI-driven ads on social media affect my online shopping choices.	10	48	33	11	01
	QI	AI improves my trust in online shopping platforms	04	39	39	16	05
Perception of AI-driven Personalization and Security.	QP	AI personalization improves my shopping experience by showing relevant products.	00	42	34	12	15
	QP	I feel comfortable sharing my data with AI-driven	06	25	47	15	10





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(Perception= P)		online shopping platforms.					
	QP	AI-based fraud detection makes online shopping safer.	09	38	41	12	03
AI and Customer Satisfaction. (Satisfaction = S)	QS	AI helps improve delivery speed and order tracking.	09	44	32	13	05
	QS	I am satisfied with how AI enhances my overall online shopping experience.	05	49	36	10	03
	QS	I would prefer AI-driven online shopping platforms over traditional ones due to better recommendations and convenience.	05	46	38	10	04

Table:9

Correlations		gender	QA	QI	QP	QS
gender	Pearson Correlation	1	-.050	-.048	.069	-.043
	Sig. (2-tailed)		.619	.632	.491	.669
	N	103	103	103	103	103
QA	Pearson Correlation	-.050	1	.588**	.381**	.688**
	Sig. (2-tailed)	.619		<.001	<.001	<.001
	N	103	103	103	103	103
QI	Pearson Correlation	-.048	.588**	1	.512**	.742**
	Sig. (2-tailed)	.632	<.001		<.001	<.001
	N	103	103	103	103	103
QP	Pearson Correlation	.069	.381**	.512**	1	.517**
	Sig. (2-tailed)	.491	<.001	<.001		<.001
	N	103	103	103	103	103
QS	Pearson Correlation	-.043	.688**	.742**	.517**	1
	Sig. (2-tailed)	.669	<.001	<.001	<.001	
	N	103	103	103	103	103

Correlation is significant at the 0.01 level (2-tailed).

Table:10

Correlations		age	QA	QI	QP	QS
age	Pearson Correlation	1	-.027	.038	.095	.029
	Sig. (2-tailed)		.786	.701	.341	.770
	N	103	103	103	103	103
QA	Pearson Correlation	-.027	1	.588**	.381**	.688**
	Sig. (2-tailed)	.786		<.001	<.001	<.001
	N	103	103	103	103	103
QI	Pearson Correlation	.038	.588**	1	.512**	.742**
	Sig. (2-tailed)	.701	<.001		<.001	<.001
	N	103	103	103	103	103
QP	Pearson Correlation	.095	.381**	.512**	1	.517**
	Sig. (2-tailed)	.341	<.001	<.001		<.001
	N	103	103	103	103	103
QS	Pearson Correlation	.029	.688**	.742**	.517**	1



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	Sig. (2-tailed)	.770	<.001	<.001	<.001	
	N	103	103	103	103	103
Correlation is significant at the 0.01 level (2-tailed).						

Table:11

Correlations						
		education	QA	QI	QP	QS
education	Pearson Correlation	1	-.055	-.040	-.167	-.101
	Sig. (2-tailed)		.584	.691	.091	.312
	N	103	103	103	103	103
QA	Pearson Correlation	-.055	1	.588**	.381**	.688**
	Sig. (2-tailed)	.584		<.001	<.001	<.001
	N	103	103	103	103	103
QI	Pearson Correlation	-.040	.588**	1	.512**	.742**
	Sig. (2-tailed)	.691	<.001		<.001	<.001
	N	103	103	103	103	103
QP	Pearson Correlation	-.167	.381**	.512**	1	.517**
	Sig. (2-tailed)	.091	<.001	<.001		<.001
	N	103	103	103	103	103
QS	Pearson Correlation	-.101	.688**	.742**	.517**	1
	Sig. (2-tailed)	.312	<.001	<.001	<.001	
	N	103	103	103	103	103
Correlation is significant at the 0.01 level (2-tailed).						

Table:12

Correlations						
		occupation	QS	QA	QI	QP
occupation	Pearson Correlation	1	-.044	-.009	-.010	-.160
	Sig. (2-tailed)		.663	.925	.922	.106
	N	103	103	103	103	103
QS	Pearson Correlation	-.044	1	.688**	.742**	.517**
	Sig. (2-tailed)	.663		<.001	<.001	<.001
	N	103	103	103	103	103
QA	Pearson Correlation	-.009	.688**	1	.588**	.381**
	Sig. (2-tailed)	.925	<.001		<.001	<.001
	N	103	103	103	103	103
QI	Pearson Correlation	-.010	.742**	.588**	1	.512**
	Sig. (2-tailed)	.922	<.001	<.001		<.001
	N	103	103	103	103	103
QP	Pearson Correlation	-.160	.517**	.381**	.512**	1





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	Sig. (2-tailed)	.106	<.001	<.001	<.001	
	N	103	103	103	103	103
Correlation is significant at the 0.01 level (2-tailed).						

Table:13

		Correlations				
		income	QS	QA	QI	QP
income	Pearson Correlation	1	.041	.129	.081	-.009
	Sig. (2-tailed)		.680	.193	.417	.930
	N	103	103	103	103	103
QS	Pearson Correlation	.041	1	.688**	.742**	.517**
	Sig. (2-tailed)	.680		<.001	<.001	<.001
	N	103	103	103	103	103
QA	Pearson Correlation	.129	.688**	1	.588**	.381**
	Sig. (2-tailed)	.193	<.001		<.001	<.001
	N	103	103	103	103	103
QI	Pearson Correlation	.081	.742**	.588**	1	.512**
	Sig. (2-tailed)	.417	<.001	<.001		<.001
	N	103	103	103	103	103
QP	Pearson Correlation	-.009	.517**	.381**	.512**	1
	Sig. (2-tailed)	.930	<.001	<.001	<.001	
	N	103	103	103	103	103
Correlation is significant at the 0.01 level (2-tailed).						

Table:14

		Correlations				
		frequently	QS	QA	QI	QP
frequently	Pearson Correlation	1	.282**	.131	.101	.106
	Sig. (2-tailed)		.004	.186	.310	.285
	N	103	103	103	103	103
QS	Pearson Correlation	.282**	1	.688**	.742**	.517**
	Sig. (2-tailed)	.004		<.001	<.001	<.001
	N	103	103	103	103	103
QA	Pearson Correlation	.131	.688**	1	.588**	.381**
	Sig. (2-tailed)	.186	<.001		<.001	<.001
	N	103	103	103	103	103
QI	Pearson Correlation	.101	.742**	.588**	1	.512**
	Sig. (2-tailed)	.310	<.001	<.001		<.001
	N	103	103	103	103	103
QP	Pearson Correlation	.106	.517**	.381**	.512**	1
	Sig. (2-tailed)	.285	<.001	<.001	<.001	
	N	103	103	103	103	103
Correlation is significant at the 0.01 level (2-tailed).						





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Table: 15 Correlation Between Gender and AI Variables

Variable	QA (Awareness)	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	-0.050	-0.048	0.069	-0.043
Significance (p-value)	0.619	0.632	0.491	0.669

Table:16 Correlation Between Age and AI Variables

Variable	QA (Awareness)	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	-0.027	0.038	0.095	0.029
Significance (p-value)	0.786	0.701	0.341	0.770

Table:17 Correlation Between Education and AI Variables

Variable	QA (Awareness)	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	-0.055	-0.040	-0.167	-0.101
Significance (p-value)	0.584	0.691	0.091	0.312

Table:18 Correlation Between Occupation and AI Variables

Variable	QA (Awareness)	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	-0.009	-0.010	-0.160	-0.044
Significance (p-value)	0.925	0.922	0.106	0.663

Table:19 Correlation Between Income and AI Variables

Variable	QA (Awareness)	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	0.129	0.081	-0.009	0.041
Significance (p-value)	0.193	0.417	0.930	0.680

Table:20 Correlation Between AI Awareness (QA) and Other AI-Related Variables

Variable	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	0.588	0.381	0.688
Significance (p-value)	<0.001	<0.001	<0.001

Table:21 Correlation Between AI Impact on Shopping Behaviour (QI) and Other AI-Related Variables

Variable	QP (Perception)	QS (Satisfaction)
Pearson Correlation	0.512	0.742
Significance (p-value)	<0.001	<0.001

Table:22 Correlation Between AI Perception (QP) and Customer Satisfaction (QS)

Variable	QS (Satisfaction)
Pearson Correlation	0.517
Significance (p-value)	<0.001

Table:23 Correlation Between Shopping Frequency and AI Variables

Variable	QA (Awareness)	QI (Impact on Behaviour)	QP (Perception)	QS (Satisfaction)
Pearson Correlation	0.282	0.131	0.101	0.106
Significance (p-value)	0.004	0.186	0.310	0.285





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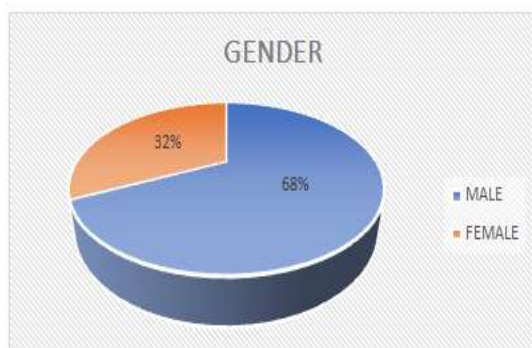


Fig:1

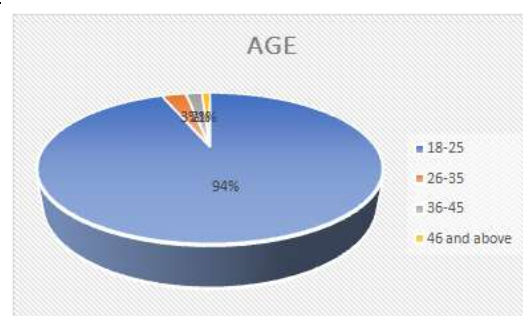


Fig:2

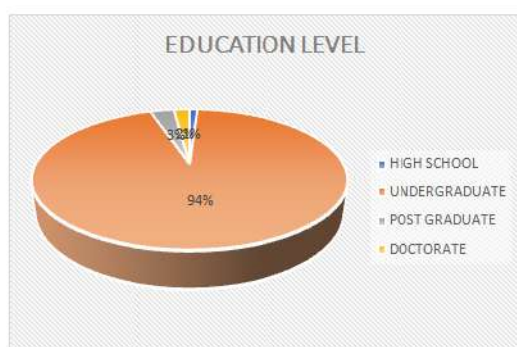


Fig:3

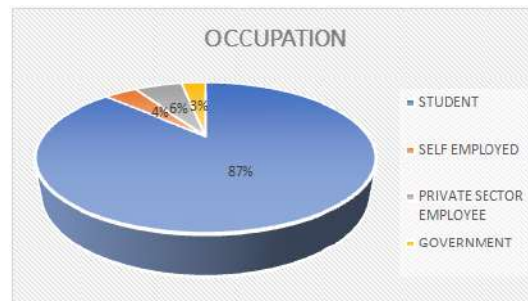


Fig:4

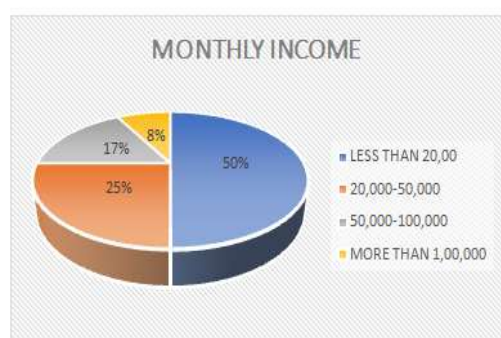


Fig:5



Fig:6





The Effectiveness of Mirror Therapy Versus Action Observation Therapy to Improve Upper Limb Motor Function in Sub-Acute Stroke - A Comparative Study

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ABSTRACT

Stroke is one of the primary causes of disabilities, which lead to limitation in the everyday activities of patients. Upper limb motor impairment is one of the major dysfunctions in stroke and very limited recovery is seen in most of the patients. This study aimed to compare the efficacy of Mirror therapy (MT) and Action observation therapy (AOT) along with conventional physical therapy in patients with stroke. It was a randomized comparative trial where 30 stroke patients aged between 40- 60 years were allocated into 2 groups, Group A (n=15) received MT and Group B (n=15) received AOT, additionally both the groups also received conventional physical therapy. The intervention period was 5 days per week for 3 weeks. The outcome measures used were Chedoke Arm & Hand Activity Inventory (CAHAI) and motor assessment scale (MAS) for assessment of the upper extremity motor function. Independent t-test found that both groups showed statistically significant improvement in upper limb motor function based on CAHAI and MAS scores. However, the AOT group had a greater improvement as compared to MT group. Such betterment was evidenced by the intragroup comparison of scores of pre-and post-treatment. AOT is a potential kind of treatment to enhance the motor function of the upper limb in patients with sub-acute stroke.

Keywords: Stroke, Mirror Therapy, Action Observation Therapy, Upper-Limb Motor Recovery, Upper-Limb Motor Function, mirror neuron





INTRODUCTION

Stroke is “rapidly developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin”.[1] It is the major contributor of death & disability in the world. Majority of the patients become functionally dependent and experience difficulties in most of the activities of daily living after an episode of stroke. At least 85% of stroke patients experience hemiplegia and upper-extremity function of at least 69% of patients is damaged. Stroke causes damage to the nervous system which leads to motor & sensory dysfunction, spasticity, impaired mobility, increased tendon reflexes, lack of coordination, reduced contribution to society along with reduced opportunity to return to professional disability-adjusted life-year activities.[2] The most common sequel after stroke is the impairment of upper limb motor function and control, leading to restriction of activities such as reaching, grasping, and manipulation.[3,4] As a consequence patient lacks social participation and has reduced quality of life. Therefore recovery of upper extremity function is of utmost importance which can be achieved using targeted therapeutic intervention like Mirror Therapy and Action Observation Therapy. Both these treatment techniques work by activating the Mirror Neuronal System (MNS). The MNS is a class of neural substrates that discharges during action observation (AO) and action execution.[5,6]. The MNS is also associated with various human functions, such as motor preparation, motion imitation, language, and emotion recognition.[7] Mirror therapy is widely and effectively used rehabilitation approach where the reflection (visual input) of a moving non-affected limb gives the illusion of movement in the affected limb. This is achieved by placing a mirror between the arms or legs.[8] It activates brain neurons to their fullest potential for motor performance. This therapeutic method makes use of visual feedback in order to increase neuroplasticity changes and to induce motivation through this feedback throughout training.[9] The mirror neurons in our brain get activated when motions are imitated & these neurons further interact with motor neurons. By activating signals in areas of the brain including mirror neurons, MT is able to contribute to improvements in representation as well as motor movement of the affected limb.[10] AOT is a motor-based method that incorporates cognitive techniques for stroke motor recovery. Patients watch some movements and actions of healthy subjects on a video or a live show; afterwards, the patients should try to imitate and perform those actions.[11] When an action is performed and when it is observed, it stimulates the MNS through AOT leading to neural reorganization and motor relearning in response to various afferent inputs and visual feedback. AOT enhances motor learning and performance improving the upper limb function in stroke patients.[12] So it might be possible to change cortical motor representations as well as motor recovery of impaired limbs after stroke by the activation of MNS during the AOT process.[13] Therefore, the objective of this study was to compare two techniques namely MT (Mirror Therapy) with AOT (Action Observation Therapy) along with conventional physical therapy in improving the upper limb motor function in sub-acute stroke patients.

MATERIALS AND METHODS

It was an experimental study conducted in various hospitals & rehabilitation centres of Kamrup Metropolitan City, Guwahati, Assam. The study received ethical clearance from the Human Ethical Committee of The Assam Royal Global University. Inclusion Criteria were: Diagnosis of haemorrhagic or ischemic stroke, sub-acute stage (1 to 3 months post unilateral stroke onset), age between 40 & 60 years, Fugl Meyer Assessment baseline score between 20 & 60 and capability to participate in assessment sessions and study therapy. Exclusion Criteria were global or receptive aphasia, severe negligence, or health issues that influenced the utilization of the upper limbs or caused severe pain, impaired cognition (MMSE<21) and visual impairments.

Procedure

Each group received three weeks of MT (Group A) and AOT (Group B) along with conventional physical therapy for 5 days per week for 3 weeks with each session lasting for 60 minutes approximately. They were informed about the do's & don'ts during the intervention period on the 1st day of the intervention. The two outcome measures i.e. CAHAI & MAS were taken at baseline (day '0') and on the 15th day i.e. immediately after treatment. Table 1, 2 & 3





illustrates the exercises performed in both the groups. In Mirror Therapy, a mirror was positioned in the patient's mid sagittal plane as part of the MT treatment protocol. The participants were instructed to see the reflection of unaffected arm movements in a mirror as if it had been the affected arm. The participants in AOT were frequently instructed to watch and carefully notice the actions carried out by the healthy people in the videos (observation phase) and after that physically practice similar actions (execution phase). Range of motion exercises for the elbow, wrist, hand & fingers were performed along with action oriented & task oriented exercises for the upper limb in both the groups using a mirror box (Group A) & a computer (Group B) respectively

RESULTS

SPSS (Statistical Package of Social Sciences) version 27 was utilized to check the results with a significance level of 95%. All the quantitative variables were tallied among the 2 groups by utilizing the independent t-test to check whether the pre and post-intervention CAHAI & MAS scores differ significantly (p -value <0.001). Based on CAHAI and MAS results, both groups showed statistically significant improvement in upper limb motor function. Such betterment was evidenced by the intragroup comparison of pre-and post-treatment scores with a p -value <0.001 . Table 3. shows that a Cohen's d value of 1.458 implies that the mean difference in the increase of CAHAI score after intervention between Group A and Group B was large, approximately 1.458 times the pooled standard deviation. This suggests a substantial and significant difference in the effectiveness of the intervention in improving CAHAI scores. Group B was significantly better in increasing CAHAI scores compared to Group. A Cohen's d value of 1.349 implies that the mean difference in the increase of MAS score (Table 4) after intervention between Group A and Group B is large, approximately 1.349 times the pooled standard deviation. This suggests a substantial and significant difference in the effectiveness of the intervention in improving MAS scores. Group B was significantly better at increasing MAS scores compared to Group A. Table 5 shows that the total scores on the CAHAI and MAS saw a bigger increase in the group that participated in AOT than they did in the MT group.

DISCUSSION

Patients who have suffered a stroke almost always experience paralysis in their upper limbs. Because of this, functional activities are limited, and more than half of all hemiplegic patients experience either long-term or permanent disability in functioning of the arm following a stroke. In this context, the functionality of the upper limbs is essential for the execution of specific activities, and the therapeutic value of this aspect should be highlighted within the context of rehabilitation programs.[14,15]. The objective of this research was to assess and contrast the effectiveness of MT and AOT with regard to upper limb motor function. The sub-acute stroke patients were split into two groups to assess the efficacy of two different treatment methods i.e., MT ($n=15$) and AOT ($n=13$) with CAHAI (Chedoke Arm and Hand Activity Inventory) and MAS (Motor Assessment Scale) as outcome measures. Both the groups showed statistically significant improvement in functional ability and motor control of upper limb function however the AOT group showed better results. (p -value <0.001) The mirror therapy group showed notable amount of progress after three weeks in the upper limb function with mirror box. In order to regain functional ability that has been impaired as a result of stroke, MT uses the brain's capacity to reorganize itself through a process known as neuroplasticity, despite the fact that the particular processes by which they occur are not fully understood.[16,17]. Garry *et al* performed transcranial magnetic stimulation during mirror illusions on healthy subjects and demonstrated that movement of normal hand activates the primary motor cortex excitability, that controls the affected hand (which is hidden behind the mirror).[18] When the movements of the reflected hand are noticed, the Mirror Neuronal System (MNS) is able to activate motor procedure, and it can even be the reason for the hand that is hidden from view behind the mirror to move. In addition, the MNS is responsible for controlling movement while attempting to move both hands at the same time. This aspect of the system contributes to an improvement in bimanual spatial coupling when the job at hand requires the use of both hands. In addition, the movement of both sides of the body through the illusion created by the mirror caused neuronal activation in the region of the brain that is responsible for alertness as well as spatial awareness.[19] Our findings that MT shows effectiveness in promoting



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motor recovery in the upper limb are supported through outcomes of the earlier research that examined the impact of MT & virtual movement training on upper limb function in chronic stroke patients. This research found that both treatments resulted in an improvement of more than the 33 percent in upper-limb FMA items. (Stevens JA *et al.* 2003). [20] The Action observation therapy group experienced a significant boost in muscle control, co-ordination and range of motion. The reason is that when brain makes an effort to imagine, observe, or carry out an action, a certain type of visuomotor neuron called mirror neuron is engaged. The activation. of motor neurons in the spinal cord & cerebral cortex can occur through both passive observation and the imitation of an activity. The mirror neuronal system plays a crucial role in improvement of the upper limb function.[21, 22] A 2014 study by Patrizio Sale *et al.* explored the clinical impact of action observation (AO) on upper limb functional recovery in sub-acute stroke patients. They randomly assigned 67 ischemic stroke subjects. Fugl-Meyer (FM) and Box and Block Test (BBT) were used to measure hand function recovery. It was concluded that AOT in the sub-acute period increases dexterity recovery in right-hemisphere stroke patients.[23]. Action observation treatment was found to be an effective method for enhancing arm and hand motor function, gait velocity, walking ability, and regular activity performance in patients who experienced a stroke, according to a study conducted by Peng *et al.* in 2019.[24]The findings of Mauro Mancuso *et al.*, 2021 proposed that AOT contributed to improved motor recovery in sub-acute stroke patients who have moderate to severe upper limb damage in the initial phase after experiencing the stroke.[25] This concept aligns with the findings in our current study, particularly regarding the improvement showed by the use of action observation therapy. The possible reasons for the higher improvement shown by action observation therapy group as compared to the MT group could be visual feedback with activation of motor neurons in the spinal cord & cerebral cortex. These in association with continuous motivation by visual assessment of the result showed gradual improvement in upper limb movement and control. Mirror neurons theory gives the theoretical basis of improvement in action observation therapy. AOT is an effective intervention for improving post-stroke upper limb function.[26.27] AOT promotes increased upper limb motor recovery compared to task-oriented training. Improvement in FMA-UE scores was seen in subacute stroke with moderate to severe impairments ($p < 0.05$).[28] Meaningful action observation training could possibly enhance the effects of activity/occupation-based interventions on occupational performance and satisfaction, as well as cortical-spinal excitability.[29] Improvements in upper limb motor function were seen in both the outcome measures following AOT and mirror treatment. In sub-acute stroke patients, AOT appears to be a potential way of treatment that could improve upper limb motor function.

Limitations and future recommendation

The sample size was small. There was no follow-up for the patients. The study was confined to stroke patients in the sub-acute stage only, acute or chronic stages of stroke were not included. Further studies can be conducted with a larger population with long-term follow-up and on different stages of stroke.

Conflict of Interest

No conflict of interest

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Table.1: Action-oriented exercises for Upper limb

1.	Squeezing and releasing the fist	Repeat 3 sets of 15 reps
2.	Opening and closing of the hand	Repeat 3 sets of 15 reps
3.	Tapping of the fingers on the table	Repeat 3 sets of 15 reps
4.	Oppose (touching) each finger to the thumb one by one	Repeat 3 sets of 15 reps
5.	With the hand closed, lifting each finger, including the thumb, one at a time	Repeat 3 sets of 15 reps

Table.2: Task-oriented exercises for the Upper limb

1.	“Handle objects using different types of grips, turning objects in the hand (complex rotation), pick up different small objects (beads or paper clips), put clothes pegs on the lip of a cup, insert pegs in a board, etc	Repeat 3 sets of 15 reps
2.	Grasp and release objects with different textures (balls, sponges, etc.)	Repeat 3 sets of 15 reps
3.	Pick up and move various objects (balls, sticks, cubes, cup etc.) in different directions and in different pathways/sequences in order to complete the goal of a game	Repeat 3 sets of 15 reps
4.	Turn over playing card	Repeat 3 sets of 15 reps
5.	Colour, connect the dots to make a drawing, copy shapes on a piece of paper	Repeat 3 sets of 15 reps
6.	Wipe, clean and dust the table with cloths with different textures (scouring pad, soft sponge, silk cloth, etc.)	Repeat 3 sets of 15 reps”

Table.3: Conventional Physiotherapy

1.	Passive and active-assisted range of motion exercises of the hip (flexion, extension, abduction, and adduction)	Repeat 2 sets of 10 reps
2.	Passive and active-assisted range of motion exercises of the knee (flexion and extension),	Repeat 2 sets of 10 reps
3.	Passive and active-assisted range of motion exercises of the ankle (dorsiflexion, plantar flexion, eversion, and inversion).	Repeat 2 sets of 10 reps
4.	Bridging exercises.	Repeat 3 sets of 3 reps
5.	Prolonged and gradually progressive stretching of hamstrings, calf, and quadriceps.	Repeat 3 sets of 3 reps
6.	Balance and coordination exercises- One leg stand, heel walking & toe walking	Repeat 2 sets of 3 reps

Table.4: CAHAI score comparison between Group A & Group B

Groups	Parameters	Mean	Std. Deviation	Correlation (p-value)	t-test (p-value)	Cohen's d
Group A (Mirror Therapy)	Pre intervention	38.80	3.19	0.899 (<0.001)	11.421 (<0.001)	2.949
	Post intervention	43.00	3.16			
Group B (Action Observation Therapy)	Pre intervention	37.20	2.68	0.461 (0.084)	9.472 (<0.001)	2.446
	Post intervention	45.00	3.36			





Table.5: MAS score comparison between Group A & Group B

Groups	Parameters	Mean	Std. Deviation	Correlation (p-value)	t-test (p-value)	Cohen's d
Group A (Mirror Therapy)	Pre intervention	34	2	0.939 (<0.001)	5.123 (<0.001)	1.323
	Post intervention	35	2			
Group B (Action Observation Therapy)	Pre intervention	34	2	0.686 (0.005)	7.690 (<0.001)	1.986
	Post intervention	36	1			

Table.6: Comparison between the groups

	Group A	Group B	t-test	Cohen's d
Mean (CAHAI)	4.20 ± 1.42	7.80 ± 3.19	3.992 (<0.001)	1.458
Mean (MAS)	1.00 ± 0.76	2.33 ± 1.18	3.696 (<0.001)	1.349

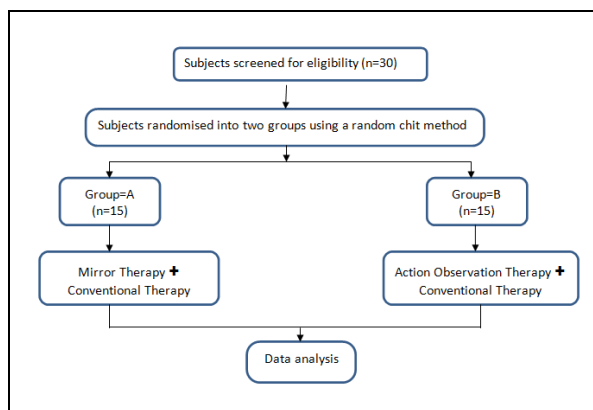


Figure 1: Flow chart of the participants

Figure.2: Mirror Therapy and Action Observation Therapy

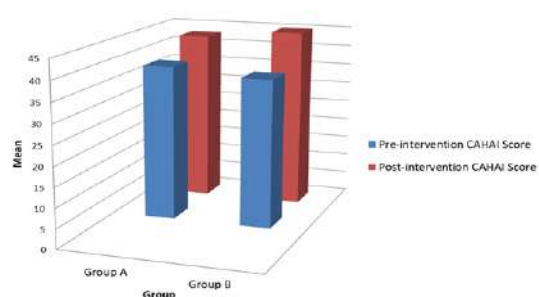


Figure 3: Comparison of Pre-and Post-intervention CAHAI scores of both groups

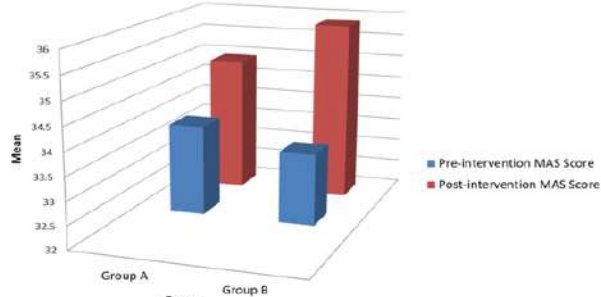


Figure 4: Comparison of Pre-and Post-intervention MAS scores of both the groups





Regulatory Challenges in Approval of Paediatric Vaccines

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ABSTRACT

The approval of paediatric vaccines presents unique regulatory challenges due to the need to balance stringent safety requirements with ethical and logistical complexities. Unlike adult vaccines, paediatric vaccines must account for physiological and immunological differences in children, necessitating age-stratified clinical trials and specific formulations. Ethical concerns, such as obtaining informed consent from guardians and ensuring minimal risk to participants, further complicate trial designs. Regulatory frameworks, including the Paediatric Research Equity Act (PREA) in the U.S. and Paediatric Investigation Plans (PIPs) in Europe, mandate comprehensive paediatric-specific studies, which often prolong the approval process. Key challenges include recruiting participants for paediatric trials, managing public hesitancy stemming from safety concerns (e.g., the Dengvaxia controversy), and harmonizing global regulatory standards. Despite advancements, such as accelerated pathways for urgent vaccines like COVID-19, paediatric vaccines often face delays in market entry due to the need for extended safety and efficacy monitoring. Collaborative global efforts, innovative trial designs, and robust post-marketing surveillance are essential to overcoming these obstacles and ensuring timely access to life-saving immunizations for children.

Keywords: Paediatric Research Equity Act (PREA), Paediatric Investigation Plans (PIPs), Regulatory Challenges, Paediatric Vaccines, Ethical Considerations, Clinical Trials





INTRODUCTION

Regulatory Challenges in Paediatric Vaccine Approval

Developing and approving paediatric vaccines is a complex process governed by stringent regulatory standards aimed at ensuring safety, efficacy, and ethical compliance. Unlike vaccines for adults, paediatric vaccines face unique challenges due to the physiological, immunological, and developmental differences in children, as well as ethical considerations in conducting clinical trials. Regulatory agencies, including the FDA, EMA, and WHO, have developed frameworks to address these challenges, but the process remains arduous and lengthy.

Key Regulatory Challenges:

1. Ethical Considerations in Paediatric Trials

Informed Consent: Children cannot provide informed consent, requiring parental or guardian authorization. Balancing parental rights with the child's best interests adds complexity to trial design.

Trial Safety: Regulators require evidence that trials minimize risk, leading to delayed inclusion of paediatric populations until adult safety data is available.

Placebo Use: Ethical dilemmas arise in withholding effective treatments, particularly for life-threatening diseases.

Paediatric-Specific Safety and Immunogenicity Data

Children have distinct immune responses compared to adults, necessitating separate studies to determine optimal dosage, schedule, and formulations. Adverse event profiles can differ significantly in children, requiring larger and more prolonged studies to ensure safety.

Regulatory Requirements

Paediatric Investigation Plans (PIPs) in Europe and the Paediatric Research Equity Act (PREA) in the U.S. mandate the development of vaccines for paediatric populations. Stringent requirements for age-stratified data, from neonates to adolescents, often prolong the approval process.

Logistical Challenges

Recruiting participants for paediatric trials is challenging, as parents may hesitate to enroll their children due to perceived risks. Maintaining compliance with vaccination schedules during trials requires meticulous planning and coordination.

Global Regulatory Harmonization

Vaccine developers must navigate differing regulatory requirements across countries, complicating global paediatric vaccine approval.

Public Trust and Vaccine Hesitancy

Paediatric vaccines face heightened scrutiny due to their target population, where public backlash can significantly impact acceptance (e.g., the Dengvaxia controversy).

Examples of Paediatric Vaccine Regulatory Challenges:

RSV Vaccines: Past trials for RSV vaccines in infants led to severe adverse effects, delaying further development for decades. **HPV Vaccine Extension:** Expanding HPV vaccine use to younger age groups required significant data on long-term safety and efficacy. **COVID-19 Vaccines:** Paediatric trials were delayed until sufficient adult safety data was collected, resulting in staggered approvals.

1. **Preclinical Research:** Laboratory experiments are conducted to evaluate fundamental vaccine mechanisms, immunogenicity, and toxicity using animal models, typically mice and primates.





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2. **IND Application:** The developer of the vaccine submits an Investigational New Drug (IND) application to the regulatory agency (such as the FDA), seeking permission to advance to human clinical trials. The regulatory agency reviews preclinical data to assess if the vaccine is safe for human trials.
3. **Phase I Trials:** Emphasizes on ensuring safety. The vaccine is usually tested on a small group of healthy adults, and sometimes older children (if paediatric trials start early). This stage is essential to establish the safety of the vaccine and determine the appropriate dosage.
4. **Phase II Trials:** Increased testing on a bigger sample size (multiple hundred) possibly involving children in the specified age range. The main focus of this stage is to examine the immune response, determine the best dosage, and ensure the safety of the vaccine in a larger group of people.
5. **Phase III Trials:** More expansive and varied groups of children are being included to test the vaccine's ability to prevent illness and ensure its safety in paediatric populations. This stage frequently includes numerous participants from different regions and populations.
6. **NDA/BLA Submission:** Following the clinical trials, a comprehensive submission is sent to the regulatory agency. This covers information from every stage of testing (I-III), production methods, and suggested product packaging. It also involves the implementation of pharmacovigilance strategies to oversee post-approval adverse reactions.
7. **Regulatory Review:** Regulatory bodies (such as the FDA) meticulously examine every piece of data available. They frequently consult with independent expert advisory committees to confirm that the benefits of the vaccine exceed its risks, especially among children.
8. **Approval Decision:** If the vaccine is approved after the regulatory review, it can be used for paediatric patients. Nevertheless, in certain scenarios, like during an emergency use authorization, the vaccine might be subject to additional surveillance or granted conditional approval.
9. **Post-Marketing Surveillance (Phase IV):** Ongoing observation of how the vaccine works outside of clinical trials, particularly to detect any uncommon adverse reactions. Systems such as the Vaccine Adverse Event Reporting System (VAERS) in the U.S. are used to monitor vaccines.
10. **Ongoing Assessment and Reauthorization:** Continuous assessment is necessary to guarantee ongoing safety and effectiveness, including regular reviews of reports on adverse events. Changes to recommendations or dosing may happen if new safety issues emerge.

Table1: Key Differences Between General and Paediatric Vaccine Development Table 2: Comparison of Regulatory Agency Fees and Considerations for Vaccine Approvals Table 3: Regulatory Application Fees and Considerations for General and Paediatric Vaccines

Key Observations

1.Fee Exemptions for Public Health Needs:

- o Many agencies (e.g., FDA, EMA, Health Canada) offer fee waivers or reductions for paediatric vaccines addressing priority health conditions or part of public health programs.

2.No Explicit Differentiation in Standard Fees:

- o Some regulatory bodies (e.g., WHO, PMDA) do not differentiate between general and paediatric vaccine application fees.

3.Paediatric Incentives:

- o Paediatric vaccines often benefit from regulatory incentives such as reduced fees, expedited reviews, and additional guidance (e.g., EMA's **Paediatric Regulation**, FDA's **Paediatric Exclusivity** provisions).

Table 4: Comparison of Development Timelines for General and Paediatric Vaccines

Regulatory Challenges for Paediatric Vaccines

1.Ethical Constraints:

- o Due to their vulnerability, clinical trials involving children must adhere to stringent ethical guidelines.
- o the requirement for proxy consent from parents or guardians adds difficulty.



**Ashish and Koushik****2.Age-Specific Testing:**

Multiple subgroups (such as infants, toddlers, and adolescents) are sometimes needed in paediatric studies in order to account for variations in immunological responses that occur with developmental stages. Adults have different dose optimization requirements for safety and effectiveness.

3.Immunization Schedules:

o Paediatric vaccinations need to be compatible with co-administered vaccines and follow current immunization schedules.

4.Long-Term Safety:

o To track long-term effects, regulators require comprehensive post-market studies, especially for innovative vaccination platforms like mRNA.

5.Global Health Priorities:

o Vaccines for childhood diseases including pneumococcal infections and rotavirus must be available and reasonably priced in low-income areas.

Table 5: Key Differences Between General and Paediatric Vaccine Development Aspects

Clinical Trial Design

A strict structure is used for designing clinical trials for paediatric vaccines in order to guarantee safety, effectiveness, and ethical compliance. Because of their physiological, immunological, and developmental variations from adults, paediatric populations provide particular problems. In order to handle this complexity and comply with ethical and legal requirements, trial designs must be customized. Figure 2: Strategies for Paediatric Vaccine Approval Table 6: Vaccine Submission and Approval Trends (2019–2024) Figure 3: FDA Vaccine Approval Trends (2019–2024): Total, Approved, and Paediatric Vaccines Figure 4: FDA Vaccine Rejection Trends (2019–2024): Total, Rejected, and Paediatric Vaccines Table 7: Vaccine Submission and Approval Trends by Year (2019–2024) Figure 5: EMA Vaccine Approval Trends (2019–2024): Total, Approved, and Paediatric Vaccines Figure 6: Annual Vaccine Submissions and Rejections by EMA: Total and Paediatric Vaccines (2019-2024*)

Case Studies**Pfizer's Respiratory Syncytial Virus (RSV) Vaccine for Infants**

In 2020, the FDA did not approve Pfizer's RSV vaccine for infants and young children after an application was filed for approval. The agency requested more safety data from ongoing studies and did not approve the vaccine at that time for broader use in paediatric populations.

AstraZeneca COVID-19 Vaccine for Children:

AstraZeneca's Vaxzevria vaccine faced delays in approval for pediatric populations, especially after reports of blood clotting issues in younger adults. The vaccine was not initially approved for use in children in many countries, including the U.S., due to these safety concerns.

Sanofi and GlaxoSmithKline's COVID-19 Vaccine:

In 2022, Sanofi and GSK's COVID-19 vaccine also faced delays in approval, including for paediatric populations, due to a request from the FDA for additional safety and efficacy data. They did not face outright rejection, but their development timeline for children was extended.

SARS-CoV2 prefusion spike delta TM (CoV-2 preSdTM) augmented with AS03:

Decision by the European Medicines Agency (EMA) dated February 14, 2022, concerning changes to a pediatric investigation plan for a COVID-19 vaccine created by Sanofi Pasteur.

The vaccine is named "SARS-CoV2 prefusion spike delta TM (CoV-2 preSdTM) augmented with AS03."

- It is given through an intramuscular injection.

- The item is marked as "no longer permitted"

Target group: Individuals from birth up to but not including 18 years old



**Ashish and Koushik****Comprises two clinical trials**

Study 1 (VAT00003): A randomized, altered double-blind controlled trial comparing the vaccine to an active comparator or a placebo.

Study 2 (VAT00009): An open-label, non-controlled investigation targeting immunocompromised pediatric subjects.

- The completion of the plan is anticipated by March 2025.
- Comprises a postponement for certain actions
- No issues were raised about possible long-term safety/effectiveness concerns.
- The decision was directed to Sanofi Pasteur located in Lyon, France.

The change was proposed on November 22, 2021.

The Pediatric Committee evaluated and approved the suggested modifications.

The choice is in accordance with several EU regulations, such as Regulation (EC) No 1901/2006.

This document represents a formal acceptance of modifications to an existing paediatric investigation plan, though it's worth noting that the medicinal product is no longer authorized^[16]

RESULTS

Paediatric vaccines: 12-18 years average development time, with longer regulatory review periods

Approval Trends (2019-2024)**FDA:**

- Higher overall approval rates for general vaccines compared to paediatric vaccines
- Increasing trend in total vaccine submissions (12 in 2019 to 20 in 2023)
- Paediatric vaccine approvals remained relatively stable (2-5 per year)

EMA

- Similar pattern of increasing submissions (8 in 2019 to 17 in 2023)
- Lower overall submission numbers compared to FDA
- Consistent paediatric vaccine approval rates (1-4 per year)

Key Challenges Identified:

- Ethical constraints due to children's vulnerability
- Need for age-specific testing across multiple subgroups
- Complexity of integrating with existing immunization schedules
- Stringent long-term safety monitoring requirements
- Cost and accessibility concerns, especially in low-income regions

CONCLUSION

Paediatric vaccine development presents a complex regulatory landscape characterized by stringent safety protocols, extended timelines, and comprehensive ethical oversight, particularly when compared to general vaccines. While regulatory bodies offer financial incentives through fee waivers and reductions for public health priorities, the process demands specialized trial designs and age-stratified testing to account for developmental differences across paediatric populations. Enhanced long-term safety monitoring requirements, though leading to delayed approvals, are crucial for ensuring vaccine safety in vulnerable populations. The challenge lies in balancing these rigorous standards with the need for timely, affordable access to vaccines, especially in developing regions, highlighting the global significance of efficient paediatric vaccine development and approval processes.





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1. Regulatory Complexity

- Paediatric vaccine development faces more stringent requirements and longer timelines compared to general vaccines. Additional ethical oversight and safety considerations significantly impact the approval process.

2. Cost Implications

Various regulatory bodies offer fee waivers or reductions for paediatric vaccines. Special considerations exist for vaccines addressing public health priorities.

3. Development Considerations

Age-stratified testing requirements add complexity. Need for specialized trial designs to account for developmental differences. Importance of compatibility with existing vaccination schedules.

4. Safety Priority

Enhanced focus on long-term safety monitoring for paediatric populations. Stricter safety requirements often lead to delayed approvals compared to adult versions.

5. Global Impact

Need for balanced approach between rigorous safety standards and timely access. Importance of maintaining affordability and accessibility, especially in developing regions.

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Table.1: Key Differences Between General and Paediatric Vaccine Development

Aspect	General Vaccine Development	Paediatric Vaccine Development
Target Population	Adults or general population (e.g., elderly, specific risk groups).	Specific paediatric age groups (e.g., neonates, toddlers, adolescents).
Preclinical Research	Animal models generally include adult specimens to assess safety and efficacy.	Additional studies on younger or developing animal models may be required to evaluate age-specific responses.
Phase 1 Clinical Trials	Small group of healthy adult volunteers to assess safety and dosage.	Rarely initiated directly in children; may follow safety validation in adults.
Phase 2 Clinical Trials	Larger group, generally includes adults or broader target populations.	Conducted in paediatric subgroups stratified by age (e.g., infants, toddlers, adolescents).
Phase 3 Clinical Trials	Large-scale trials, often involving thousands of participants across diverse demographics.	Trials are often smaller; require precise age-specific safety and efficacy data, including immune response maturation.
Trial Initiation	Can be initiated in the target population directly if preclinical data supports safety.	Delayed until adult safety data is available due to ethical concerns for children.
Dosage Considerations	Standardized for adults or adjusted based on weight and metabolism.	Dosage must be optimized for developmental stages and smaller body weights.
Regulatory Requirements	Submission focuses on general population safety and efficacy.	Requires a Paediatric Investigation Plan (PIP) in some regions (e.g., EMA). Additional ethical and safety





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		data for children are mandatory.
Approval Timeline	May be faster as adult populations are less vulnerable and require fewer ethical considerations.	Often slower due to additional paediatric-specific studies and ethical approvals.
Special Ethical Oversight	Fewer restrictions as long as informed consent is obtained.	Strict ethical review to minimize risks; informed consent from guardians is mandatory.
Immunogenicity Testing	Focuses on achieving robust immunity across age ranges.	Must consider age-related immune system maturity and potential interference with maternal antibodies in young infants.
Post-Approval Monitoring	Standard pharmacovigilance systems apply.	More intensive monitoring for long-term safety and rare side effects in paediatric populations.
Fee Structure	Standard regulatory fees based on application type.	Some agencies (e.g., FDA, EMA) offer reduced fees or waivers for paediatric vaccines addressing public health needs.
Regulatory Guidance	General vaccine guidelines (e.g., FDA, WHO).	Requires compliance with additional paediatric-specific regulations (e.g., EMA's Paediatric Regulation).
Emergency Use Pathways	Expedited pathways are often available.	Emergency pathways may apply but typically lag behind adult vaccines due to safety prioritization.

Table.2: Comparison of Regulatory Agency Fees and Considerations for Vaccine Approvals

Regulatory Agency	Country	Application Fee	Additional Considerations
<i>FDA</i>	United States	\$3,510,218 (Standard) / \$1,755,109 (Small Business)	Paediatric vaccines may be exempt from PDUFA fees under Vaccines for Children Program Additional costs for facility inspections and manufacturing site approvals
<i>EMA</i>	European Union	€296,900 (2024)	Discounts/waivers for paediatric medicines under Paediatric Regulation Reduced fees/waivers for SMEs and priority health issues Paediatric Investigation Plan submission required
<i>WHO Prequalification</i>	Global	\$25,000 dossier assessment fee	Possible additional inspection fees
<i>Health Canada</i>	Canada	CAD \$396,430 (Full New Drug Submission)	Fee waivers possible for public health priorities and special access programs
<i>PMDA</i>	Japan	¥21,000,000 (New vaccine approval)	Post-approval annual fees and periodic inspections
<i>TGA</i>	Australia	AUD \$280,000	Waivers/reductions possible for orphan drugs and public health initiatives





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Table.3: Regulatory Application Fees and Considerations for General and Paediatric Vaccines

Regulatory Body	Application Fee for General Vaccines	Application Fee for Paediatric Vaccines	Differences/Notes
FDA (USA)	\$3,510,218 for a Biologics License Application (BLA) (FY 2024).	Generally, exempt under the Vaccines for Children (VFC) program.	Paediatric vaccines are often fee-exempt if included in the VFC program; otherwise, fees are the same.
EMA (Europe)	€296,900 (as of 2024). This fee covers the evaluation of a marketing authorization application (MAA) for vaccines.	Fee reductions or waivers for paediatric vaccines under the Paediatric Regulation.	Paediatric vaccines addressing priority health needs or rare diseases may qualify for significant discounts.
Health Canada	CAD \$396,430 (~\$290,000 USD) for a New Drug Submission (NDS).	Fee waivers or reductions may apply for public health priorities.	Paediatric vaccines targeting critical public health needs may receive special consideration.
PMDA (Japan)	¥21,000,000 (~\$140,000 USD) for new vaccine approval.	No specific differentiation in standard fees.	Paediatric vaccines do not have explicit fee waivers, but fees are consistent with general vaccine submissions.
TGA (Australia)	AUD \$280,000 (~\$181,000 USD) for vaccine evaluation.	Waivers or reductions for vaccines addressing public health priorities, including paediatric needs.	Paediatric vaccines for public health issues may benefit from reduced fees.
WHO Prequalification	\$25,000 dossier assessment fee for general vaccines.	Same as general vaccine fees.	No fee differentiation specifically for paediatric vaccines.
MHRA (UK)	£103,000 (~\$128,000 USD) for new vaccine evaluation.	Fee reductions for vaccines that benefit public health, including paediatric vaccines.	Similar to EMA, fee reductions may apply for paediatric vaccines addressing unmet needs.

Table.4: Comparison of Development Timelines for General and Paediatric Vaccines

Stage	General Vaccines	Paediatric Vaccines
Preclinical Research	1–5 years	1–5 years (based on adult studies)
Clinical Trials	6–10 years	5–10 years
Regulatory Review	1–2 years	1–3 years (stricter scrutiny)
Total Development Time	10–15 years (average)	12–18 years (average)





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Table.5: Key Differences Between General and Paediatric Vaccine Development Aspects

Aspect	General Vaccines	Paediatric Vaccines
Target Population	General population	Infants, children, and adolescents
Trial Size	Large, diverse groups	Age-stratified cohorts
Ethical Concerns	Standard ethical requirements	Higher scrutiny due to vulnerability
Approval Timeframe	Accelerated during pandemics	Slower due to stricter safety reviews
Dosing	Standard adult doses	Age- and weight-specific doses

General and Paediatric Vaccine Development Aspects

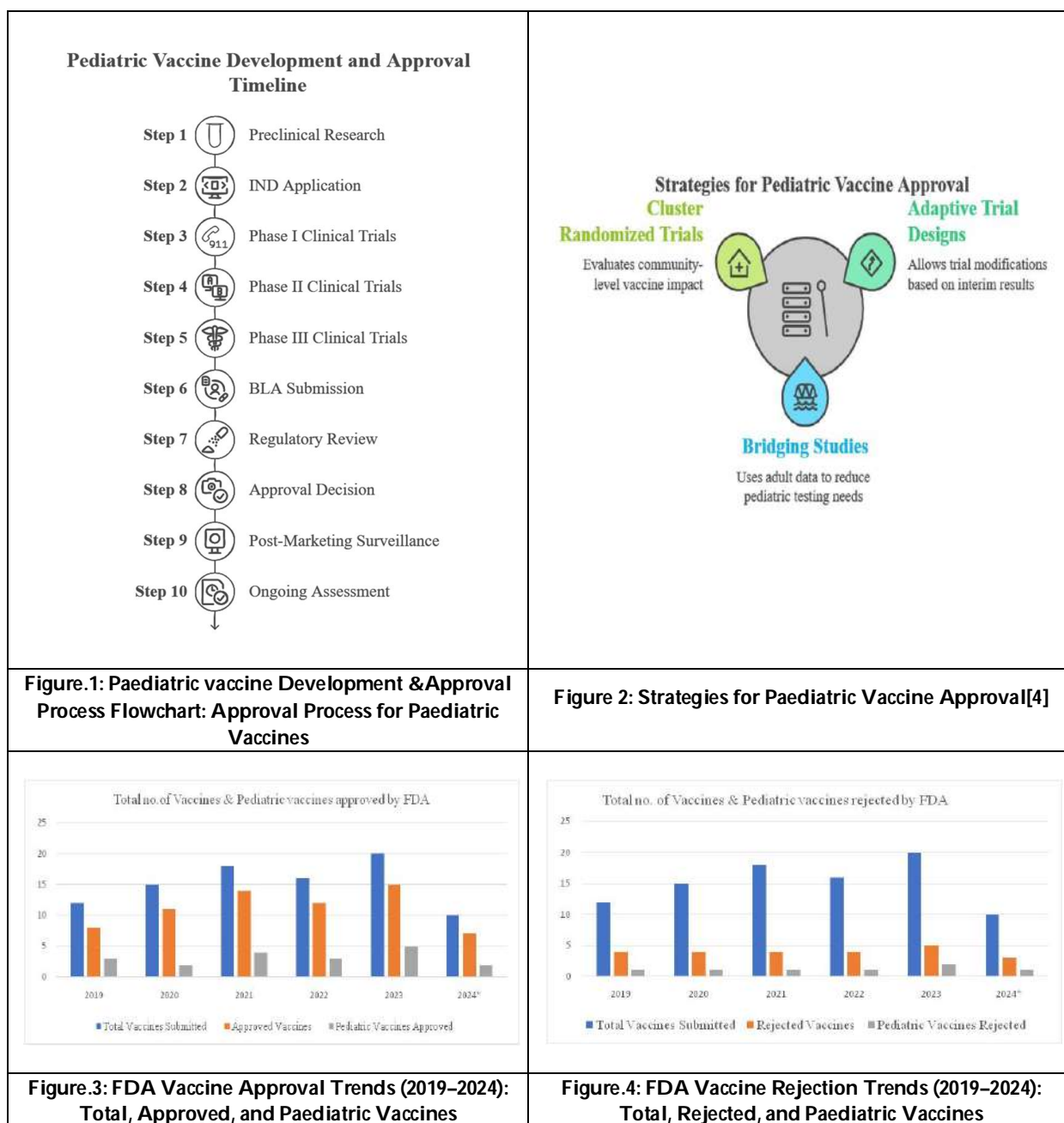
Table.6: Vaccine Submission and Approval Trends (2019–2024) Vaccine vs Paediatric vaccines (FDA)

Year	Total Vaccines Submitted	Approved Vaccines	Rejected Vaccines	Paediatric Vaccines Approved	Paediatric Vaccines Rejected	Notable Vaccines
2019	12	8	4	3	1	Influenza vaccines, HPV vaccines
2020	15	11	4	2	1	COVID-19 initial vaccines
2021	18	14	4	4	1	Pediatric COVID-19 vaccines
2022	16	12	4	3	1	RSV vaccines
2023	20	15	5	5	2	Updated COVID boosters
2024*	10	7	3	2	1	Emerging technologies

Table.7: Vaccine Submission and Approval Trends by Year (2019–2024) Vaccines vs Paediatric vaccines (EMA)

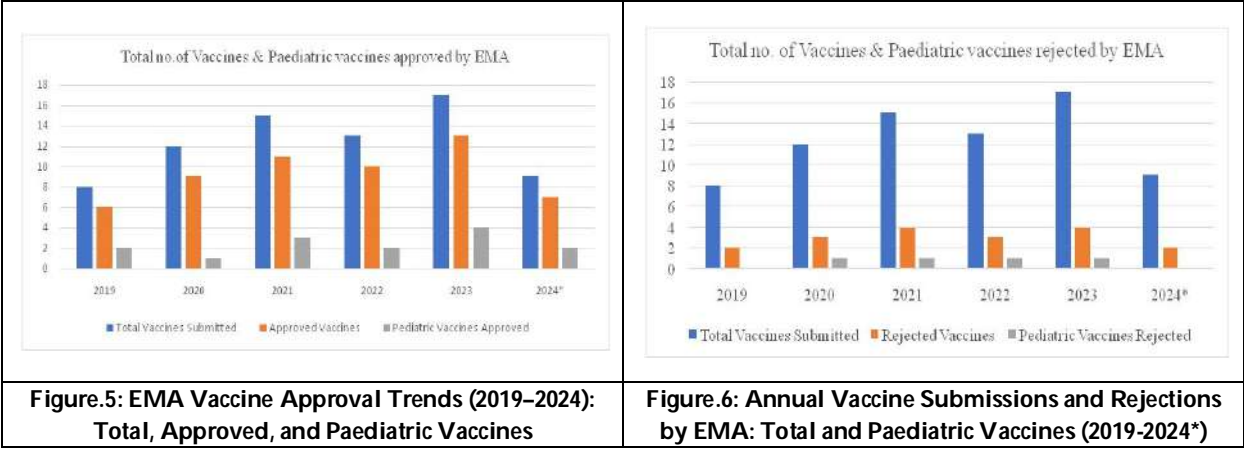
Year	Total Vaccines Submitted	Approved Vaccines	Rejected Vaccines	Paediatric Vaccines Approved	Paediatric Vaccines Rejected	Notable Vaccines
2019	8	6	2	2	0	Influenza vaccines
2020	12	9	3	1	1	COVID-19 initial vaccines
2021	15	11	4	3	1	Paediatric COVID-19 vaccines
2022	13	10	3	2	1	RSV vaccines
2023	17	13	4	4	1	Updated COVID boosters
2024*	9	7	2	2	0	Emerging technologies







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Nanoemulgel - based Delivery of Leflunomide: A Review of Therapeutic Potential for Rheumatoid Arthritis

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ABSTRACT

Rheumatoid arthritis (RA) is a debilitating chronic inflammatory disease primarily affecting the joints, leading to pain and significant mobility issues. Leflunomide is an effective immunomodulatory drug used in RA treatment, but its clinical application is often hampered by poor bioavailability and side effects from oral administration. Advances in nanotechnology have introduced nanoemulgels as a novel delivery system to potentially overcome these limitations. This review paper examines the development, characterization, and therapeutic efficacy of nanoemulgel-based delivery systems for leflunomide in the management of RA. The benefits of nanoemulgels, such as enhanced drug solubility, improved dermal penetration, and sustained release, are discussed in detail, highlighting their role in increasing bioavailability and minimizing systemic adverse effects. The paper also covers the methods of preparation, evaluation techniques, and the effectiveness and safety of leflunomide-loaded nanoemulgels. Additionally, the review addresses the current obstacles and future directions in the field, underscoring the necessity for further clinical research to validate the therapeutic advantages of this delivery system. The adoption of nanoemulgel-based leflunomide delivery in RA treatment protocols has the potential to significantly improve patient outcomes by providing a more efficient and safer alternative to traditional therapies.



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Keywords: Rheumatoid arthritis (RA), Leflunomide, Nanoemulgel, Immunomodulatory drugs, Dermal penetration, Nanotechnology.

INTRODUCTION TO LEFLUNOMIDE

Leflunomide is a key medication in the management of autoimmune diseases, particularly rheumatoid arthritis (RA). Introduced to the market in 1998 under the brand name Arava, leflunomide has become an essential part of therapeutic regimens aimed at modifying disease progression and managing symptoms in various autoimmune conditions.[1]

Chemical Structure and Mechanism of Action

Leflunomide is classified as a pyrimidine synthesis inhibitor and acts as a prodrug, meaning it is converted into its active metabolite, teriflunomide, in the body. The chemical structure of leflunomide is defined by its hydantoin core with a trifluoromethyl group, enhancing its efficacy and selectivity.[2] Teriflunomide specifically inhibits dihydroorotate dehydrogenase (DHODH), an enzyme crucial for the de novo synthesis of pyrimidine nucleotides. This inhibition results in a decrease in the proliferation of activated lymphocytes, which play a central role in autoimmune inflammation. Consequently, leflunomide effectively modulates the immune response and reduces the production of inflammatory cytokines.[3]

Clinical Applications

Leflunomide's primary indication is the treatment of rheumatoid arthritis, a chronic inflammatory disorder characterized by joint pain, swelling, and potential joint damage. Clinical studies have shown that leflunomide is effective in reducing symptoms and slowing disease progression in RA patients.[4] In addition to RA, leflunomide is utilized for other conditions such as psoriatic arthritis, where it helps manage skin and joint symptoms. Its application in systemic lupus erythematosus is also under investigation, reflecting its broad potential in autoimmune disease management.[2]

Pharmacokinetics and Dosage

Leflunomide is administered orally, with good bioavailability and peak plasma concentrations achieved approximately 6-12 hours after ingestion. The drug's pharmacokinetics is characterized by a long half-life, approximately two weeks, due to the prolonged presence of its active metabolite, teriflunomide. The typical dosing regimen includes an initial loading dose of 100 mg daily for the first three days, followed by a maintenance dose of 20 mg daily. This dosing strategy aims to achieve rapid therapeutic levels while minimizing the risk of adverse effects.[4]

Safety and Side Effects

While leflunomide is effective, it is not without its risks. Common adverse effects include gastrointestinal disturbances such as diarrhea and nausea, along with dermatological reactions. More serious concerns involve hepatotoxicity and teratogenic effects. Regular monitoring of liver function tests is recommended to mitigate the risk of liver damage. Additionally, leflunomide should be avoided during pregnancy due to its potential to cause harm to the developing fetus. These safety considerations are crucial for ensuring the effective and safe use of leflunomide in clinical practice.[1]

Conclusion

In summary, leflunomide is a significant DMARD with a distinct mechanism of action involving the inhibition of pyrimidine synthesis. Its effectiveness in treating rheumatoid arthritis and other autoimmune conditions underscores its importance in therapeutic regimens. Ongoing research continues to explore its full potential and optimize its use across different autoimmune diseases.





Introduction to Nanoemulgel

Nanoemulgels represent a cutting-edge drug delivery system that merges the benefits of nanotechnology with those of hydrogels. This combination involves incorporating nanoemulsions within a gel matrix, which capitalizes on the enhanced solubility and bioavailability offered by nanocarriers and the localized, controlled release characteristics of hydrogels. Such a hybrid formulation is particularly effective for the delivery of poorly water-soluble drugs, providing a sustained therapeutic effect while minimizing systemic side effects. Nanoemulsions are stable isotropic mixtures comprising oil, water, and surfactants, typically with droplet sizes ranging from 20 to 200 nm. These systems significantly improve drug solubilization and protect drugs from degradation, making them suitable for delivering hydrophobic drugs. Despite their advantages, the low viscosity of nanoemulsions can limit their application in topical and transdermal therapies where prolonged site contact is necessary.[5, 6] On the other hand, hydrogels are three-dimensional, hydrophilic polymer networks that can retain large quantities of water or biological fluids. Their gel-like consistency ensures good adhesion to the skin or mucous membranes, creating a reservoir for the sustained release of the encapsulated drug. When nanoemulsions are incorporated into a hydrogel matrix, the resulting nanoemulgels combine the high drug-loading capacity and enhanced penetration of nanoemulsions with the extended residence time and controlled release properties of hydrogels.[7, 8] This synergistic approach not only enhances the pharmacokinetic profile of drugs such as leflunomide but also improves patient compliance through a non-invasive and user-friendly delivery method. Recent research has shown the potential of nanoemulgels in various therapeutic areas, highlighting their versatility and efficacy.[9, 10]

Advantages of Nanoemulgel

Nanoemulgels are an advanced drug delivery system that merges the beneficial properties of nanoemulsions and hydrogels. This combination provides several key advantages, addressing significant challenges in drug formulation and delivery.

1. **Improved Drug Solubility and Bioavailability:** Due to their nano-sized droplets, nanoemulsions enhance the solubility of drugs that are poorly soluble in water. This increase in surface area allows for better drug absorption, leading to higher bioavailability.[5,6]
2. **Controlled and Prolonged Drug Release:** The gel matrix in nanoemulgels ensures a controlled and sustained release of the drug. This continuous release helps maintain therapeutic drug levels for extended periods, reducing the need for frequent dosing and improving patient compliance.[7]
3. **Better Penetration and Absorption:** The small droplet size of nanoemulsions allows them to penetrate biological barriers more effectively, such as the skin or mucous membranes. This enhanced penetration is particularly useful for topical and transdermal drug delivery, enabling deeper tissue targeting.[8]
4. **Enhanced Stability of Encapsulated Drugs:** Nanoemulsions protect drugs from environmental degradation, such as oxidation and hydrolysis. When these emulsions are incorporated into a gel matrix, they gain an extra layer of protection, further stabilizing the drug.[9]
5. **Versatility in Drug Formulation:** Nanoemulgels can be formulated to deliver a wide range of drugs, including both hydrophobic and hydrophilic compounds. This versatility makes them suitable for various therapeutic applications, such as dermatology, ophthalmology, and transdermal drug delivery.[9]
6. **Ease of Application and Increased Patient Compliance:** Nanoemulgels are easy to apply and spread over the skin or mucous membranes due to their gel-like texture. This user-friendly application, combined with their controlled release properties, leads to higher patient adherence, especially for long-term treatments.[10]

In summary, nanoemulgels offer a comprehensive approach to drug delivery by addressing issues related to solubility, stability, and patient compliance. Their ability to provide controlled release, enhance penetration, and protect drug integrity makes them a valuable platform for various pharmaceutical applications.

Applications of Nanoemulgels

Nanoemulgels offer a broad spectrum of applications across different therapeutic areas due to their unique combination of properties. They provide an effective platform for drug delivery, addressing challenges related to solubility, stability, and controlled release.



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1. **Dermatology:** Nanoemulgels are widely used in dermatological applications for the treatment of skin disorders. They can efficiently deliver active ingredients to the deeper layers of the skin, making them effective for treating conditions such as acne, psoriasis, and eczema. The enhanced penetration and prolonged release of drugs through nanoemulgels result in better therapeutic outcomes and improved patient adherence.[5]
2. **Transdermal Drug Delivery:** Nanoemulgels are ideal for transdermal drug delivery systems. They facilitate the delivery of drugs across the skin barrier, providing a non-invasive alternative to oral or injectable routes. This method is particularly useful for systemic delivery of pain relievers, anti-inflammatory drugs, and hormones. The controlled release properties of nanoemulgels ensure consistent drug levels in the bloodstream, reducing the need for frequent dosing.[6]
3. **Wound Healing:** Nanoemulgels have shown promise in wound healing applications. Their ability to deliver antimicrobial and anti-inflammatory agents directly to the wound site helps in faster healing and reduces the risk of infection. The gel matrix maintains a moist environment, which is conducive to the wound healing process.[7]
4. **Cosmeceuticals:** The cosmetic industry also benefits from nanoemulgels, particularly in the formulation of products aimed at improving skin hydration, reducing signs of aging, and delivering active ingredients like vitamins and antioxidants. Nanoemulgels provide a stable medium for these ingredients, ensuring their efficacy and prolonged release on the skin.[9]
5. **Ophthalmology:** In ophthalmic drug delivery, nanoemulgels offer several advantages, including improved drug stability and enhanced penetration through the ocular tissues. They can be used to treat various eye conditions, such as glaucoma and infections, by delivering drugs more effectively to the targeted site within the eye. The gel matrix helps in prolonging the contact time of the drug with the ocular surface, leading to better therapeutic efficacy.[10]
6. **Rheumatoid Arthritis:** Nanoemulgels are used for the topical delivery of anti-rheumatic drugs. The localized delivery system helps to concentrate the drug at the site of inflammation, providing relief from pain and inflammation with reduced systemic side effects. This method is especially beneficial for chronic conditions like rheumatoid arthritis where long-term medication is required.[11]
7. **Antifungal Treatments:** Nanoemulgels can be formulated for the topical treatment of fungal infections. The small size of the nanoemulsion droplets allows for deeper penetration into the infected tissue, enhancing the effectiveness of the antifungal agents. This approach can be particularly useful for treating conditions such as athlete's foot and fungal nail infections.[12]
8. **Antiviral Therapies:** In the field of antiviral treatments, nanoemulgels are used to deliver antiviral agents directly to the site of infection. This targeted approach improves the concentration of the drug at the site, enhancing its efficacy while minimizing systemic exposure and side effects. Nanoemulgels have shown potential in the treatment of viral infections like herpes simplex.[13]
9. **Pain Management:** Nanoemulgels are also effective for the localized delivery of analgesics and anesthetics. By providing a controlled release of the drug, they offer prolonged pain relief for conditions such as muscle pain, joint pain, and post-operative pain. The gel matrix ensures that the drug remains in contact with the affected area, maximizing its therapeutic effect.[14]
10. **Hormone Replacement Therapy:** Nanoemulgels are utilized in hormone replacement therapies, providing a non-invasive method for delivering hormones like estrogen and testosterone. The controlled release properties of the gel matrix ensure steady hormone levels, reducing the frequency of administration and improving patient compliance.[15]
11. **Anti-Acne Treatments:** In the treatment of acne, nanoemulgels can deliver anti-acne agents more effectively to the sebaceous glands. The enhanced penetration and sustained release of the drug help in reducing acne lesions and preventing new outbreaks. This method improves the overall efficacy of acne treatments.[16]
12. **Psoriasis Treatment:** Nanoemulgels are used for the topical delivery of medications for psoriasis. They help in managing the symptoms by delivering anti-inflammatory and immunosuppressive agents directly to the affected areas. The controlled release mechanism ensures prolonged drug action, reducing the frequency of application.[17]
13. **Hair Regrowth and Scalp Treatments:** Nanoemulgels are beneficial in formulations aimed at treating scalp conditions and promoting hair regrowth. By delivering active ingredients directly to the hair follicles, they



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enhance the effectiveness of treatments for conditions like alopecia. The gel matrix provides a stable environment for the active ingredients, ensuring their sustained release and prolonged action.[18]

These applications illustrate the versatility and efficacy of nanoemulgels in various therapeutic areas. Their ability to enhance drug delivery, improve stability, and provide controlled release makes them a valuable tool in modern pharmaceutical formulations.

Materials Required for Nanoemulgel Preparation

1. **Active Pharmaceutical Ingredient (API):** The selection of the API is pivotal in nanoemulgel formulation, influencing the therapeutic outcome. APIs are chosen based on their intended therapeutic effect, such as anti-inflammatory, antimicrobial, or analgesic properties. For instance, diclofenac is commonly used for its anti-inflammatory effects, while clotrimazole is employed for antifungal purposes.[19]
2. **Aqueous Phase:**
 - o **Components:** The aqueous phase generally consists of distilled water or other aqueous solutions.[19]
 - o **Purpose:** It acts as the continuous phase in the nanoemulsion, contributing to the gel's final consistency and stability.
3. **Oils:**
 - o **Types:** Oils used in nanoemulgel formulations can include mineral oils, vegetable oils (e.g., soybean or olive oil), and essential oils (e.g., lavender oil).[20]
 - o **Purpose:** These oils constitute the oil phase of the nanoemulsion, facilitating the solubilization of lipophilic drugs and enhancing skin penetration.
4. **Preservatives:**
 - o **Types:** Preservatives like Benzalkonium Chloride or Phenoxyethanol are incorporated to prevent microbial growth.[20]
 - o **Purpose:** They ensure the microbiological safety of the formulation and maintain the API's efficacy over time.
5. **Gelling Agents:**
 - o **Types:** Gelling agents such as Carbopol, Hydroxyethyl Cellulose (HEC), and Xanthan Gum are commonly used.[21]
 - o **Purpose:** These agents transform the nanoemulsion into a gel-like consistency, impacting the rheological properties and ensuring proper application and adherence to the skin.
6. **Surfactants:**
 - o **Types:** Surfactants are critical for stabilizing nanoemulsions by reducing interfacial tension between the oil and water phases. Common surfactants include Polysorbate 80 (Tween 80) and Span 80 for their non-ionic properties, as well as Sodium Lauryl Sulfate, an ionic surfactant. [21]
 - o **Purpose:** They stabilize the nanoemulsion, ensuring a uniform distribution of the API throughout the gel matrix.
7. **Co-Surfactants:**
 - o **Types:** Co-surfactants such as ethanol and propylene glycol are used to enhance the stability and formation of nanoemulsions. [22]
 - o **Purpose:** They assist in reducing droplet size and improving the formulation's overall stability.
8. **pH Adjusters:**
 - o **Types:** pH adjusters such as Sodium Hydroxide or Hydrochloric Acid are used.[22]
 - o **Purpose:** They adjust and stabilize the pH of the formulation, which is crucial for maintaining both the stability of the gel and its compatibility with the skin.

Equipment Required

1. **Homogenizer:**
 - o Essential for reducing the droplet size of the oil phase and achieving a uniform nanoemulsion.[20]
2. **Ultrasonic Processor:**
 - o Used to further decrease the size of nanoemulsion droplets, enhancing stability and improving the gel's texture.[19]
3. **Stirring Equipment:**



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- Magnetic stirrers or overhead stirrers are used to mix components uniformly, ensuring a consistent formulation.[20]
- 4. **Viscometer:**
 - Measures the viscosity of the gel, which is crucial for determining the appropriate consistency and spreadability.[21]
- 5. **pH Meter:**
 - Monitors and adjusts the pH of the formulation to ensure it remains within the desired range for stability and skin compatibility.[22]

Methods for Preparation of Nanoemulgel

Preparation of Nanoemulsion

High-Energy Methods

- **High-Pressure Homogenization:**

- **Principle:** This method utilizes high pressure to force an emulsion through a narrow valve, resulting in the reduction of droplet sizes to the nanometer range due to intense shear forces.
- **Process:**
 1. Combine oil and aqueous phases with surfactants to create a coarse emulsion.
 2. Pass the emulsion through a high-pressure homogenizer multiple times.
 3. The high shear forces break down droplets to nanoscale dimensions (20-200 nm).
- **Advantages:** Provides uniform droplet size and high stability.[23]

- **Ultrasonication:**

- **Principle:** Ultrasonic waves create cavitation bubbles in the liquid, which implode and generate high shear forces that break up the oil droplets into nanoscale sizes.
- **Process:**
 1. Prepare a coarse emulsion by mixing the oil and aqueous phases.
 2. Use a probe sonicator to subject the emulsion to ultrasonic waves.
 3. Adjust parameters like amplitude and duration to achieve the desired droplet size.
- **Advantages:** Effective for small-scale production; suitable for heat-sensitive materials.[24]

Low-Energy Methods

- **Spontaneous Emulsification:**

- **Principle:** This method relies on the spontaneous formation of nano-sized droplets when oil and water phases are mixed with surfactants at specific ratios.
- **Process:**
 1. Mix the oil phase with the aqueous phase and surfactants.
 2. The mixture forms nano-sized droplets spontaneously due to the phase inversion or self-emulsification process.
- **Advantages:** Low energy requirement; suitable for temperature-sensitive substances.[25]

Preparation of Gel

Hydrogel Formation

- **Physical Gelation:**

- **Principle:** Physical gels form through non-covalent interactions such as hydrogen bonding or ionic interactions between polymer chains.
- **Process:**
 1. Dissolve gelling agents (e.g., carbomers, alginates) in water.
 2. Allow the gelation process to occur through spontaneous or controlled pH/temperature changes.
- **Advantages:** Simple preparation; ideal for drugs requiring a gentle environment.[26]

- **Chemical Gelation:**

- **Principle:** Chemical gels are formed through the covalent cross-linking of polymers using cross-linking agents.



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1. Dissolve polymers and cross-linking agents in water.
2. Allow cross-linking reactions to form a three-dimensional gel network.

o Advantages: Creates more robust gels with controlled release properties.[27]**• Thermoreversible Gelation:****o Principle:** Thermoreversible gels form or gel upon heating or cooling due to temperature-sensitive gelling agents.**o Process:**

1. Prepare a solution of thermoreversible gelling agents (e.g., agar, gellan).
2. Adjust temperature to induce gel formation or dissolution.

o Advantages: Allows for temperature-controlled gel formation; useful for controlled drug delivery.[28]**Methods for Incorporating Nanoemulsion into Gel**

Integrating nanoemulsions into gels is a vital technique in drug delivery, leveraging the enhanced bioavailability and controlled release properties of nanoemulsions alongside the ease of application and localized treatment provided by gels.

Simple Mixing Method

This straightforward method involves directly combining the pre-prepared nanoemulsion with a gel base. It is suitable when the nanoemulsion and gel base are chemically compatible and the nanoemulsion is thermodynamically stable.

Procedure

1. **Nanoemulsion Preparation:** Formulate the nanoemulsion using high-energy methods like ultrasonication or high-pressure homogenization.[29]
2. **Gel Base Preparation:** Prepare the gel base using gelling agents such as carbomers, xanthan gum, or hydroxypropyl methylcellulose (HPMC).[30]
3. **Incorporation:** Slowly mix the nanoemulsion into the gel base while continuously stirring to ensure uniform distribution.

In Situ Gelation Method

This technique involves forming the gel after the nanoemulsion is mixed into the gel-forming solution. It is advantageous for drugs that need a controlled release profile.

Procedure

1. **Nanoemulsion Preparation:** Create the nanoemulsion using methods like microfluidization.
2. **Gel-Forming Solution:** Prepare a solution of the gelling agent in a solvent where gelation can be triggered by temperature, pH, or ionic strength changes.[31]
3. **Mixing:** Combine the nanoemulsion with the gel-forming solution.
4. **Gelation Trigger:** Induce gelation by altering environmental conditions, such as heating (for thermally responsive gels) or adding a crosslinking agent (for ionically responsive gels).

Emulsion Gel Technique

In this method, the nanoemulsion is integrated into the gel matrix during the emulsification process itself. It is especially useful for thermosensitive drugs.

Procedure

1. **Nanoemulsion Preparation:** Use low-energy emulsification methods such as phase inversion temperature (PIT) or spontaneous emulsification.[32]
2. **Gel Matrix Formation:** Add the gelling agent to the nanoemulsion either simultaneously or subsequently.



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3. **Emulsification and Gelation:** Stir the mixture at a controlled temperature to achieve gelation while maintaining nanoemulsion stability.

Sol-Gel Method

This method involves incorporating the nanoemulsion into a sol, which then transitions into a gel. It is useful for incorporating bioactive molecules that are sensitive to heat or mechanical stress.

Procedure:

1. **Nanoemulsion Preparation:** Formulate the nanoemulsion using low-energy methods like spontaneous emulsification.
2. **Sol Preparation:** Create a sol using precursors such as silica, titania, or other metal alkoxides in an aqueous or organic solvent.[33]
3. **Mixing:** Add the nanoemulsion to the sol under gentle stirring.
4. **Gelation:** Allow the sol to undergo gelation through hydrolysis and condensation reactions at room temperature or slightly elevated temperatures.

Conclusion

Various methods can be used to incorporate nanoemulsions into gels, each suitable for different active ingredients and desired release profiles. The simple mixing method is the most straightforward, while in situ gelation, emulsion gel techniques, and sol-gel methods offer more advanced approaches for controlled release and stability.

Characterization and Evaluation of Nanoemulgels

Nanoemulgels represent a cutting-edge approach in drug delivery systems, combining the benefits of nanotechnology and hydrogels to improve the bioavailability and therapeutic efficacy of hydrophobic drugs. Detailed characterization and evaluation are essential to ensure their efficacy, stability, and safety.

1. **Particle Size and Distribution** The particle size and distribution of nanoparticles within nanoemulgels are crucial parameters that influence stability, bioavailability, and therapeutic outcomes. Dynamic light scattering (DLS) is commonly employed to determine the average particle size and polydispersity index (PDI). Ideally, nanoemulgels should have a narrow size distribution with a PDI of less than 0.3, indicating uniformity. Smaller particle sizes lead to a larger surface area, enhancing drug solubility and absorption.[34]
Transmission electron microscopy (TEM) and scanning electron microscopy (SEM) provide visual confirmation of particle size and morphology.[37]
2. **Zeta Potential** Zeta potential measures the surface charge of nanoparticles and influences the stability of the nanoemulgel by affecting particle interactions. A high zeta potential (either positive or negative) typically suggests good stability due to strong electrostatic repulsion, preventing aggregation. Zeta potential is measured using a zeta potential analyzer, with values above ± 30 mV considered stable.[35]
3. **Rheological Properties** Understanding the rheological behavior of nanoemulgels is vital for their application, stability, and user compliance. Rheological studies assess the flow behavior and viscoelastic properties. Nanoemulgels should exhibit pseudoplastic behavior, where viscosity decreases with increasing shear rate, making them suitable for topical application. This ensures easy application and adherence to the skin while maintaining stability at rest. Rheometers measure parameters such as viscosity, storage modulus (G'), and loss modulus (G'').[36]
4. **Morphology and Microstructure** The morphology and internal microstructure of nanoemulgels are key to their stability and drug release properties. Techniques like TEM and SEM provide detailed images of nanoparticle shape and distribution within the gel matrix. Cryo-TEM is particularly useful for observing the internal structure in a hydrated state, preserving the natural arrangement of particles and the gel network.[37]
5. **Drug Content and Encapsulation Efficiency** Determining drug content and encapsulation efficiency is critical for assessing the therapeutic potential of nanoemulgels. High-performance liquid chromatography (HPLC) is commonly used to quantify the drug encapsulated within nanoparticles. High encapsulation efficiency ensures



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maximum therapeutic effect with minimal drug wastage. Encapsulation efficiency is calculated using the formula:

Encapsulation Efficiency (%) = (Amount of Drug Encapsulated / Total Amount of Drug Added) × 100.[39]

6. **In Vitro Release Studies** In vitro release studies are essential to understand the drug release profile from the nanoemulgel. These studies are conducted using methods like dialysis, diffusion cells, or Franz diffusion cells, analyzing the release medium over time to determine release kinetics. Controlled and sustained release profiles are preferred to enhance therapeutic efficacy and reduce dosing frequency. Release data can be fitted to kinetic models such as zero-order, first-order, Higuchi, and Korsmeyer-Peppas to understand the release mechanism.[38]
7. **Stability Studies** Stability studies assess the shelf life and robustness of nanoemulgels under various environmental conditions such as temperature, humidity, and light. These studies predict long-term behavior and ensure efficacy throughout the shelf life. Stability is evaluated by monitoring changes in particle size, zeta potential, drug content, and physical appearance over time. Accelerated stability studies expose formulations to elevated temperatures and humidity to predict stability under normal storage conditions. [38, 40]
8. **In Vivo Studies of Nanoemulgels** Evaluating nanoemulgels in vivo involves several critical parameters to ensure their efficacy, safety, and overall performance. The primary parameters for in vivo evaluation include:
 1. **Pharmacokinetic Analysis:**
 - **Objective:** To analyze the absorption, distribution, metabolism, and excretion (ADME) of the drug.
 - **Methods:** Blood samples are taken at various intervals and analyzed using techniques such as high-performance liquid chromatography (HPLC) or mass spectrometry (MS).[41]
 2. **Bioavailability Assessment:**
 - **Objective:** To measure the extent and rate at which the active drug ingredient is absorbed and reaches the site of action.
 - **Methods:** Comparative studies with conventional formulations, often using the area under the curve (AUC) from plasma concentration-time profiles.[42]
 3. **Therapeutic Efficacy Evaluation:**
 - **Objective:** To assess the clinical effectiveness of the nanoemulgel in treating the intended condition.
 - **Methods:** Utilizing disease models (e.g., arthritis models for anti-inflammatory drugs) to measure therapeutic outcomes.[43]
 4. **Toxicity Studies:**
 - **Objective:** To determine the safety profile of the nanoemulgel, including any potential adverse effects.
 - **Methods:** Conducting acute and chronic toxicity studies in animal models to monitor physiological and biochemical parameters.[44]
 5. **Skin Irritation and Sensitization Tests:**
 - **Objective:** To ensure that the nanoemulgel formulation does not cause skin irritation or allergic reactions.
 - **Methods:** Performing patch tests and histopathological examinations of the skin after nanoemulgel application.[45]
 6. **Histopathological Examination:**
 - **Objective:** To examine tissue samples microscopically for any pathological changes post-treatment with the nanoemulgel.
 - **Methods:** Collecting, processing, and examining tissue samples under a microscope.[46]

CONCLUSION

Comprehensive characterization and evaluation of nanoemulgels are essential to ensure their efficacy, stability, and safety as drug delivery systems. Techniques such as particle size analysis, zeta potential measurement, rheological studies, and in vitro and in vivo testing play crucial roles in the development and optimization of these advanced formulations. Thorough evaluation of these parameters enables the development of effective and reliable nanoemulgels for various therapeutic applications. The development of a nanoemulgel formulation for leflunomide offers a promising strategy to overcome the challenges associated with its poor solubility and limited bioavailability.



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The nanoemulsion system, characterized by its nano-sized droplets, significantly enhances the dissolution rate and facilitates better drug absorption. By incorporating the nanoemulsion into a gel matrix, the resultant nanoemulgel not only improves the topical delivery of leflunomide but also ensures prolonged retention and sustained drug release. The comprehensive characterization of the nanoemulsion, including particle size analysis, zeta potential, and morphological studies, confirms its stability and suitability for further formulation into a nanoemulgel. The selection and optimization of gelling agents are crucial steps that influence the final product's viscosity, spreadability, and overall performance. Rheological evaluations demonstrate that the nanoemulgel possesses the desired consistency and thixotropic behavior, facilitating easy application and adherence to the skin or mucosal surfaces. *In vitro* release studies indicate a controlled and sustained release of leflunomide from the nanoemulgel, suggesting potential for enhanced therapeutic outcomes. Stability studies corroborate the formulation's robustness, ensuring that the nanoemulgel remains effective under various storage conditions. In conclusion, the nanoemulgel formulation of leflunomide represents a significant advancement in drug delivery technology, offering a feasible and effective means to improve the bioavailability and therapeutic efficacy of leflunomide. This innovative approach holds substantial promise for enhancing the treatment of conditions requiring leflunomide, ultimately benefiting patients through improved clinical outcomes.

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Table.1: Available Marketed Products In Form of Nanoemulgel

Brand Name	Active Ingredient(s)	Concentration	Company	Indications	Additional Information	References
Voltaren Emulgel	Diclofenac diethylamine	1.16%	Novartis	Anti-inflammatory, analgesic	Contains propylene glycol and isopropyl alcohol for enhanced skin penetration	[47]
Nizoral Cream	Ketoconazole	2%	Janssen Pharmaceutica	Antifungal	Effective against dermatophytes, yeasts, and molds	[48]
Clindac A	Clindamycin	1%	Galderma	Acne treatment	Often combined with benzoyl	[49]



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					peroxide or retinoids for enhanced efficacy	
Voltaren Gel	Diclofenac sodium	1%	GlaxoSmithKline	Anti-inflammatory, analgesic	Alcohol-based gel formulation enhances absorption through the skin	【50】
Dovonex Cream	Calcipotriene	0.005%	Leo Pharma	Psoriasis	Vitamin D analog, often used in combination with corticosteroids for better results	【51】
Voltaren Ophtha	Diclofenac sodium	0.1%	Novartis	Postoperative inflammation in ocular surgery	Used in eye drop form, effective in reducing inflammation and pain after cataract surgery	【52】
Canesten Cream	Clotrimazole	1%	Bayer	Antifungal	Effective for the treatment of athlete's foot, jock itch, and ringworm	【53】
Retin-A Micro Gel	Tretinoin	0.1%, 0.04%	Johnson & Johnson	Acne treatment	Microsphere formulation allows for controlled release, minimizing irritation and maximizing efficacy	【54】
Metrogel	Metronidazole	0.75%, 1%	Galderma	Rosacea treatment	Reduces redness and inflammation, available in gel formulation for better skin absorption	【55】
Differin Gel	Adapalene	0.1%, 0.3%	Galderma	Acne treatment	Retinoid, helps to reduce inflammation and prevent clogged pores	【56】
Lamisil	Terbinafine	1%	Novartis	Antifungal	Effective for the	【57】





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AT Gel					treatment of athlete's foot, jock itch, and ringworm	
Fucidin Cream	Fusidic acid	2%	Leo Pharma	Antibiotic for skin infections	Effective for the treatment of impetigo, infected dermatitis, and other skin infections caused by bacteria	【58】

Table.2: Available Marketed Formulations of Leflunomide

Brand Name	Manufacturer	Dosage Form	Strength	Indications	References
Arava	Sanofi	Tablet	10 mg, 20 mg	Used to manage rheumatoid arthritis	【59】
Levolin	Torrent Pharmaceuticals	Tablet	10 mg, 20 mg	For the treatment of rheumatoid arthritis	【60】
Avara	Zydus Cadila	Tablet	10 mg, 20 mg	Treats symptoms of rheumatoid arthritis	【61】
Lefrus	Sun Pharmaceutical	Tablet	10 mg, 20 mg	Manages rheumatoid arthritis symptoms	【62】
Leflox	Alembic Pharmaceuticals	Tablet	10 mg, 20 mg	For the management of rheumatoid arthritis	【63】
Lefunomide	Intas Pharmaceuticals	Tablet	10 mg, 20 mg	Indicated for rheumatoid arthritis treatment	【64】
Arthfree	Lupin Pharmaceuticals	Tablet	10 mg, 20 mg	Used to alleviate rheumatoid arthritis symptoms	【65】





Nutritional Composition, Health Benefits and Culinary Applications of Quinoa

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ABSTRACT

Quinoa is the seed of the chenopodium quinoa plant. It's also called "pseudo grains" because it resembles the nutrients in cereal grains. Quinoa belongs to the dicotyledoneae class, the Chenopodiaceae family, and the Chenopodium genus. It is well known today that this grain is gluten-free which helps individuals with gluten allergies. It is beneficial for groups of people indulging in sports activity, lactose intolerant person, children below 6 years, female with osteoporosis, individual having anaemia, diabetes mellitus, dyslipidemia, gaining weight and wheat disease because of high nutritive values of quinoa, gluten free and therapeutic properties. Rajgira is a rich source of fiber, also contains a good amount of protein, vitamins, and minerals, and has a remarkable level of essential amino acids. Also, it has ample omega-3 fatty acid which is also beneficial for maintaining good health. In general, nutrient contents of quinoa are higher in variations per 100 g fresh weight of edible portion such as: protein (09.10–15.70 g), total fat (04.00–07.60 g) and dietary fiber (08.80–14.10 g). Quercetin and kaempferol are flavonoids present in Quinoa which have powerful antioxidant and anti-inflammatory effects in the body. Rajgira has a good impact on metabolism, cardiovascular, and gastrointestinal health in humans. This review paper includes all the nutritional properties of quinoa, its culinary applications like quinoa chikki, upma, beverages and its health benefits.

Keywords: Rajgira, Dyslipidemia, Pseudo grains, Quinoa, Chenopodium

INTRODUCTION

Since 1998, the WHO has examined obesity, an outbreak that affects the population worldwide and causes more deaths. Obesity is correlated with non-communicable diseases like cancer, cardiovascular diseases, diabetes, and others. In this framework, it is very crucial to look after the traditions and social values of the food practices that are





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off-track over time. The majority of traditional practices and beliefs for these foods are ignored, and crops are kept aside. (35) A magnificent crop that almost faded is quinoa (*Chenopodium quinoa*). Quinoa has an elevated past amid impressive civilization on the land of liberty (America). It is derived from the Inca Empire in the hills of Bolivia, Chile, and Peru. It was a staple diet for the Incas and a well-known source of food for their native descendants.

Origin and History:

Quinoa, the staple food in pre-colonial communities of the Andes, Chile, Argentina, and South America, ranged from 2° latitude on the northern side (Colombia) to 47° latitude on the southern side (Chile) (35). Quinoa is a religious pasture for the Incas, whom they termed the mother of all cereals. The Intercontinental era of Quinoa in 2013 triggers the broadening of quinoa and shows the increase in stipulation, manufacture and research of mother grain globally. The Nutritional grade of quinoa build it approved in excellent protein, this grain contains a 'n' number of functions connected to the nutrients, even being a wheat free food. (72). The cultivation has been done in the South America Andes from past 8000 years and these all are Andean species. (26), (69), (17), (39) The two out of the five main ecotypes of quinoa planting focused by the Chile, namely the coastal ecotypes and the salt flat ("salares") ecotypes. In the northern Chile, the Tarapacá and Antofagasta regions (18–25°S) have "salares" ecotype, with an altitude over 3000m. Upland native populations (Quechua and Aymara and people) have historically grown these Rajgira in these areas on salty soils with annual rainfall ranging between 100 and 200 mm from December to February during the southern hemisphere summer. On the other hand, there is proof that little quinoa genetic material from the Peruvian Andean area was introduced from the Antofagasta region. In spite of data, in Chile the "salt flat" ecotype dominates the morphology of the majority of the quinoa investigated. (18). The system of national Chilean protects the novel diversification only has one blend that has been generated and documented. A hybrid called "La Regalona" (67) has a broad spectrum of adaptability and greater yields have been developed. It can grow under short days in latitudes close to the polar latitudes up to 40° (S / N) and latitudes close to the equator. Quinoa is a novel crop for India that has far gone unnoticed by academics, business people, and commercial and experimental farmers. Quinoa can be grown commercially with great success throughout India because it responded well to a variety of agro-ecological situations, according to the findings of front-line demonstrations of the crop conducted by Dharm Singh in the different states of Rajasthan (2003–04), Haryana (2005–06), Uttar Pradesh (2005–06), Maharashtra (2006–07), and Gujarat (2007–08). Quinoa has been revered by humans as religious grain as it contains good amount of protein and remarkable amino acids in equilibrium. (28) In South America, a number of indigenous groups have historically utilized quinoa. (65). Resemble with rice, soups are made from the seeds, puffed them for morning cereal, or baked goods including biscuits, pasta, bread, tortillas, crisps, and pancakes by flouring them. (8). Similar to how spinach leaves are consumed, quinoa sprouts are added to salads. (53) Additionally, fermented seeds can be used to create beverage which is alcoholic known in South America chicha that is utilized during religious ceremonies (FAO, 2011). In addition, it is utilized contain good nutrient for feeding agricultural beast including chickens, pigs, and cattle (8).

Nutritional Composition

Quinoa is known for high level of protein and balanced amino acid profile with good levels of methionine and lysine. (61), (32) It has a certain portion of minerals and fiber, such as Calcium and Iron (5). These Polyphenols are antioxidants which are rich in quinoa. (47), (48) Rajgira is also thought to be gluten-free, making it ideal for celiac sufferers and individuals with wheat allergies. (27) (32) Rajgira is very much known for its protein content both quantitatively and qualitatively. (68) Quinoa contain very good amount of protein which is equal to the milk protein whole dried when given to the mouse. Later on, pigs were fed with quinoa which is cooked and with skimmed milk which is dried. Lysine (04.80 g/100 g) and Threonine (03.70 g/100 g), amino acids limited in traditional grains, are abundant in proteins. (14) Even if the environment has an impact on the composition of amino acid, the outstanding quality of protein is preserved. (23)

Protein

Protein participated in the building of the tissues, enzymes formation, antibodies and hormones, helps to supply the power and manage the metabolic processes (4). The protein content in quinoa is determined by the amino acids. The aromatic amino acids are tyrosine and phenylalanine scoring 86.0 of protein in raw quinoa and 85.0 proteins in



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washed quinoa. The presence of lysine and sulfur amino acids is higher. The essential amino acids content is higher as compare the other cereals (51). On the basis of dry weight, the content of protein in quinoa cereals is ranged between 9.10 to 15.70 g / 100 g⁻¹. Proteins present with in quinoa seeds majorly are albumins (35%) , globulins (37%) and a low percentage of prolamins (0.5–7.0%).

Fat

Quinoa is rich in fatty acids like linoleic and alpha-linoleic acid. It contains antioxidant in higher amount such as alpha and gamma-tocopherol. It contains oil near about 7.0%. the saturated fatty acid present in the quinoa was palmitic 10% is equal to the totally fatty acid present. The content of fat in Rajgira grains (4.0-7.6%). The nutritive value of quinoa grains and fatty acid of quinoa is analyzed by (43). Quinoa cereal contain ample amount of linoleic acid ranging between 46.60 to 58.10% and a low amount of alpha linoleic acid ranging between 06.10 to 08.44% of trans fatty acid. (60)

Fiber

There are two types of fiber in plants, on the basis of solubility that are soluble and insoluble. Examples of soluble fiber are Pectin and gums which are soluble in water, whereas examples of insoluble fiber are polysaccharides, cellulose, and hemicelluloses are water insoluble. There are two types of fibers neutral detergent fiber (NDF) and acid detergent fiber (ADF) on the digestibility. Neutral detergent fiber fractions contain hemicelluloses, cellulose, lignin, and acid neutral fiber fractions containing mainly cellulose and some lignin. The amount of fiber present in quinoa grains varied between 07.0 to 14.10%, respectively. In fiber fraction analysis of sprouted quinoa (9) significantly higher amount of neutral detergent fiber (NDF) is found, near by 77.73% NDF, than acid detergent fiber (ADF). With 78% insoluble and 22% soluble fiber Quinoa grains are considered as an excellent source of dietary fiber. (23), (33)

Carbohydrates

It is largest group of organic compound which is found in the nature. The main carbohydrate which is present in the quinoa is starch 52% to 69%. The dietary fiber in quinoa helps in indigestibility in the small intestine. It improves the absorption of the nutrients (42). The estimated amount of carbohydrates % = 100% (ash + protein + moisture + fat). The overall content of the carbohydrates in Rajgira grains is (48.5-69.8 %). High protein and low carbohydrates foods valuable to being health, due to elevated plasma glucose level not contributed. The amylopectin in the quinoa is higher than the rice varieties. The carbs consider as nutraceuticals as they showed hypoglycemic effects and lower down the effect of free fatty acids.

Essential Amino Acids

Macromolecular compounds amino acid (AA) and protein plays a crucial role in the human body as enzymatic reactions, catalysts for structural components and synthesis of protein (34). Many grains are deficient in Lysine (19). Cysteine and Methionine are two antioxidants which have potential to detoxifying the toxins and safe from wavy radiations (10).

Health Benefits

Rajgira is beneficial for groups at high risk including high indulging in sports activity, lactose intolerant person, children below 6 years, female with osteoporosis, individual having anaemia, diabetes mellitus, dyslipidaemia, gaining weight and wheat disease because of high nutritive values of quinoa, gluten free and therapeutic properties. (58).

Pharma Activity of Quinoa

The parts of quinoa including seeds, roots, stem, leaves and seeds had variety of bioactive substances. These compounds are various benefits included antioxidant, antimicrobial, antidiabetic, antifungal, anti-inflammatory and anticancer.



**Aarzo Singh and Govind Ballabh Bhatt****Antioxidant**

The property of antioxidant in Rajgira is higher as compare to other grains; it is used to prevent the diseases (16). Clinical research has shown that proteins, fiber, vitamins, minerals, saponins, phytosterols, phytoecdysteroids, and phenolics are the antioxidants that are most effective at lowering cholesterol levels (15). According to Balakrishnan and Schneider, the digestive process of quinoa flavonoids increases antioxidant capacity by a factor of two. The direct consumption of quinoa provides good amount of antioxidant. (7)

Antimicrobial

The quinoa leaves and seeds are rich in polyphenols as well as tannin which have antimicrobial property (57).

Antidiabetic

Phenolic acids, tocopherols, protein, fibre and bioactive peptides are high in quinoa. These contribute to the antidiabetic property (12). The BMI and HbA1c level reduced by having Rajgira. This helps to overcome the elevated blood glucose level and stabilize the health (1). Consumption of quinoa seeds in different amount reduces the blood glucose level, T3 and T4 in rats (25).

Anti-inflammatory

Phenolic compounds, saponins and polysaccharides are bioactive compounds contain by quinoa seeds. These are linked with the several properties like anti-inflammatory, anticancer and antioxidant (3). The ethyl acetate fraction of the Rajgira inflorescence methanolic extract includes phytochemicals with anti-inflammatory, antimicrobial, antifungal, antibacterial, cancer prevention, and cytotoxic properties, according to research (55).

Antifungal

Because of their capacity to bind with steroids in fungal membranes, quinoa saponins have antifungal action, which compromises the integrity of the membranes and results in pore development (6).

The gastroenterology at king's college London and Columbia University's department which is wheat disease hub suggested quinoa as an alternative grain, which is important source for wheat disease patients (70)

Culinary Application

Quinoa is very rich in nutrients due to its peculiar composition. It is important source of the energy as starch present in it; it gives protein of excellent quality and dietary fiber, rich in lipids. Additionally, have a good amount of minerals, vitamins and bioactive compounds like polyphenols, saponins; phytosterols etc. quinoa is a gluten free grain which has potential for human health like diabetics, celiac, gluten intolerant and others (64).

Quinoa Chikki

One of the greatest foods is chikki. Rajgirachikki is made by using Soaked Rajgira. Traditional chikki of peanut was employed as a control, and toasted quinoa grains and peanuts were used. As the percentage of quinoa was raised, the appearance, color, and flavor all enhanced due to the distinctive aroma of roasting and caramelization. Since quinoa has a gritty texture, 100% inclusion effect on both flavor and texture. A same study was conducted in (29) who created the chikki, a blend quinoa and crushed nuts. The percentage of quinoa included ranged from 60% to 100%. The difference in 60% quinoa and 40% nut received the good rating for general acceptance and moderate like. The multigrain Nutri-chikkis with roasted Bengal gram, black sesame, pumpkin seed, flax seed, ground nut, and almond earned the highest rating (8.3) of all the chikkis. The chosen mixture was deemed to have superior nutritional content, cheap manufacturing costs, and pleasant flavor (2).

Quinoa Upma

Quinoa, dalia, chana dal, onion, carrot, green peas, green pepper, curry leaves, mustard seeds, cumin, spices, salt ingredients are used in a fixed proportion. Ingredients are sun dried to be moisture free. Half teaspoon of vegetable oil and spices are used to roast the ingredients. Cooled it and stored in a jar. At Lucknow's RFRAC (Regional Food Research Analysis Centre), the tests were decided. The AOAC technique was used to determine the protein content.



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Calcium content was determined using IS: 5838:1970 and carbohydrate content was assessed using SP: 18 techniques. (56).

Quinoa Fermented Beverage

The fermentation of cereal improves the product nutritional quality and gives various benefits for human being health (49). Modern research focuses mainly on creation of novel fermented drinks of grain-based as well their beneficial and probiotic qualities (46), (20), (36). The naturally present compound in quinoa is saponins from 0.1 – 5.0 % (45). The quinoa seeds utilized in this investigation had a saponin content of 0.30 0.02%. Washing or water maceration is advised to eliminate saponins (44). The PH value decreases and increases in the total acidity during the process of fermentation (36). The rice is fermented and quinoa beverage is prepared from the different varieties (61). The PH is decreased initially in the process which is crucial to have high quality results of final products (30) and minimize the growth of pathogenic bacteria by increase in the total acidity (31).

Quinoa Dark Chocolate

Rajgira (*Chenopodium quinoa*) has protein of good quality and is a strong source of vitamin E. It was created to add 12, 16, or 20% quinoa to dark chocolate. As the proportion of quinoa in the goods rose, so did their protein content. Only 9% more vitamin E was found in the product containing 20% quinoa, whereas the number of polyphenols reduced from 23.50 to 18.0 mol pirocatechin/g. Samples containing quinoa had higher levels of the necessary amino acids. The chocolate contains 20% of quinoa, the levels of tyrosine, cysteine and methionine rise by 72, 104 and 70%, respectively. The WHO standards-compliant amino acid pattern was sufficient for human requirements. 92% of the sensory panel members gave their approval for the chocolate and quinoa. Every sample had an acceptability index of greater than 70%. At the dosages considered in this study, quinoa might be utilized, giving the dark chocolate its potential health benefits. (54).

Quinoa Pasta

Pasta most demanded product for non- celiac gluten sensitivity. Currently gluten free pasta is available in market (13). The wheat free flour which is used is made from paddy (*Oryza sativa*). Sorghum (*Sorghum bicolor*) and corn (*Zea mays*). Researches which mainly target the alternate of the wheat mixing along with starch, enzymes, emulsifiers and hydrocolloids. Changing in the functional properties of the wheat free flour is hydrothermal (22). Deficiencies of dietary fiber and iron in wheat free diet (59). The incorporation of protein isolates or nutrient-rich flours, like those from quinoa (*Chenopodium quinoa*), chickpea (*Cicer arietinum*), lupine and other legumes flours, has increased efforts to improve gluten-free products (21).

CONCLUSION

Quinoa which includes the leaves, sprouts, and microgreens, are a great source of vitamins, minerals, and health-improving substances with capabilities that include antibacterial, anticancer, anti-diabetic, antioxidant, anti-obesity, and cardioprotective effects. In addition to being wheat free, there are a superb protein, amino acids, important minerals, and omega-3 fatty acids sources. Quinoas are potential crop with high nutritional content that might help combat hunger issues and improve access to food and nutrition. Quinoas are not often eaten as vegetables anymore, nevertheless. Quinoa can be consumed as salads and as cooked veggies and in many forms. Quinoa may also be used in other gluten-free food items as functional food components. You may add the dried leaf powder to processed dishes like breads, soups, and baked goods. Greater total phenolic content Quinoa greens, which include the leaves, sprouts, and microgreens, are richest in minerals and phytochemicals that had antibacterial, anticancer, anti-diabetic, anti-inflammatory, anti-antioxidant, anti-obesity, and cardio protective properties. Quinoas are free of gluten and rich in protein, essential minerals, and amino acids. Quinoas are a promising new crop with additional value that might help reduce malnutrition and increase access to food and nutrition. When compared to grains, quinoa that has been germinated (quinoa sprouts) is said to have a greater total phenol content and antioxidant potential. The antioxidant content of quinoa sprouts rises during germination (sprouting) for up to 6–9 days, and red quinoa has





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more antioxidants than yellow quinoa. Quinoa sprouts and microgreens are a potential food for human health and nutrition, much like the sprouts and microgreens available in supermarkets today. To provide a comprehensive overview of the functional and nutritional relevance to being health and raise awareness about the usage of Rajgira as new "super vegetables" in human diets, more research is required. Now, a day's people are much more concern about their health and love to include quinoa in their diet in the form of different food products like chikki, beverages, upma, pasta and many more. It will help to overcome the nutritional deficiency among the population.

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Table.1: Nearby values of Rajgira seeds. (65),(5),(41),(38),(62),(32),(47)

Nutritional value	Vega Gálvez <i>et. al</i> (2010)	Ando H <i>et. al</i>	Nowak <i>et. al</i> (2016)	Miranda, M <i>et. al</i> (2011)	Miranda, M <i>et. al</i> (2011)	USDA (2016)	Kozioł, M. J. (1992)	Repo-Carrasco-Valencia <i>et. al</i> (2010)
Protein value (g/100g)	16.81	12.90	13.10	14.70	12.82	14.10	16.50	12.60
Carbohydrates (g/100g)	51.42	63.71	59.91	59.11	68.40	57.21	69.00	67.31
Lipids value (g/100g)	5.91	6.52	5.72	6.42	6.21	6.10	6.41	5.72
Fiber value (g/100g)	12.10	13.90	11.70	1.91	1.5	7.01	1.9	3.0





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Table.2: Essential amino acids

Essential Ammino Acid			
Ammino Acid	[Nowak <i>et al.</i> 2016] g 100 g ⁻¹ DW	[Valcarcel-Yamani B <i>et al.</i> 2012] g100 g ⁻¹ protein	[Ruales and Nair 1992] mg/g protein
Histidine	1.4-5.4	3.2	24
Isoleucine	0.8-7.4	4.4	32
Leucine	2.3-9.4	6.6	79
Lysine	2.4-7.5	6.1	51
Methionine	0.3-9.1	4.8	34
Phenylalanine	0.1-2.7	7.3	63
Threonine	2.1-8.9	3.8	38
Tryptophan	0.6-1.9	1.1	15
Valine	0.8-6.1	4.5	39

Table.3: The minerals composition of Rajgira grains. (41), (64)

MINERALS (mg 100 ⁻¹ DW)		
	[Nowak <i>et al.</i> 2016]	(Valcarcel-Yamani B <i>et al.</i> 2012)
Calcium (Ca)	27.5-148.7	32.9-874.0
Copper (Cu)	1.0-9.5	-
Iron (Fe)	1.40-16.70	05.5-81.0
Magnesium (Mg)	26.00 to 502.00	206.8-2620.0
Phosphorus (P)	140.00 to 530.0	...
Potassium (K)	696.70 to 1475.00	1201.0

Table.4: Pharma Activity of Quinoa

Therapeutic Application	Treatment	Endpoints and Outcomes	Result
Growth and development of the child (50)	Quinoa is formulated in infant food	Plasma level increased, shows as malnutrition, weight gain of the body increased	Infant quinoa food plays an important part to overcome malnutrition.
Wheat disease (wheat resistant) (71)	Quinoa should be cooked	Each digestive system parameter improvements were made to the height of the surface enterocyte cell and the quantity of intra-epithelial lymphocytes per 100 enterocytes. Serum lipid levels remained normal with a small decline in total cholesterol, LDL, HDL, and triglycerides.	It is made for the consumption of celiac patients
Risk rate of Cardiovascular (15)	Rajgira Cereal bar for 30 days daily	Triglycerides reduced, cholesterol level reduced, Low Density Lipoprotein	Reduces the cardiovascular disease risk
Symptom and sign of postmenopausal (11)	Corn is compared to quinoa flakes	Triglycerides are low, low TBARS, little cholesterol level, LDL reduced and low level of GSH	Beneficial for metabolic parameter





AI Driven Workforce Planning: Exploring Talent Acquisition and Optimization - HR Decision Paradigm for a New Strategy

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ABSTRACT

The advent of Artificial Intelligence (AI) has revolutionized workforce planning, reshaping talent acquisition and optimization strategies in Human Resources (HR). Allying AI-engaged methodologies to workforce planning is significant in this research subject, where talent acquisition and workforce planning will be the areas of interest. The study investigates how the implementation of AI impacts HR decision-making models to design effective ideas which meet today's organizational requirements. In the present study convenience sampling technique was used and questionnaires were answered by 150 HR professionals and organizational leaders to measure their self-generated views and observations about the use of AI in the determination of future supply of workforce. The article aims to assess critical measures relating to the efficiency of AI-enabled tools of talent acquisition, impacts on identifying required skills, and roles, and optimal staff placements. It is recommended that the purposeful application of AI for workforce planning should be combined with an emphasis on the ethical issues that may arise when using this kind of technology, the opportunities to reskill the workforce in order to support these ideas, or to carry out continuous evaluation to assess the impact of these ideas as they are being rolled out. This study complements existing literature on the adoption of AI in HR practices, by acknowledging both the benefits of AI adoption for the organization and its drawbacks. The study provides knowledge for organizations that aim at implementing deep learning-driven solutions to improve the management of human capital and gain long-term competitive edge.



**Shareefa Bhanu and Annette Christinal****Keywords:** Artificial Intelligence, Candidate Screening, Predictive Hiring Analytics, Recruitment Cost, Time Efficiency.

INTRODUCTION

AI-powered chatbots provide highly personalized experience and provide potential candidates with engagement during the hiring. These features enhance the candidate experience and enhance the chances of landing the best employees. However, as the authors note, there may be disadvantages associated with the use of this technology: ethical issues, threats to data privacy, and, quite possible, algorithmic prejudice. **Aggarwal (2020)** discussed where applied artificial intelligence stands now, with a focus on what has been done to talent acquisition. The authors note that AI enhances conventional recruitment processes because it increases effectiveness and reliability and makes strategic decisions. AI talent acquisition solutions apply mainly in sourcing, prescreening, communication, and initial hiring processes. Recruitment chatbots, resume parsing, and automating predictive analytics aid the recruiters in a faster and filter-free selection process and in taken out bias at the same time. In the article, the author describes the benefits of the application of AI that include; cost optimization, improving the candidate experience, and flexibility. AI to search through thousands of CVs in minutes and shortlist them according to set criteria versus job description. If AI systems use data that is biased then it will also bias itself in its decision making process. Thus, the authors support human supervision to safeguard accuracy and balance in the procedures of AI-based hiring. It also focuses on how best to implement AI by incorporating it with any prevalent human resource management systems. Finally, the article emphasizes that AI can serves as a significant contributor to the **modern world of recruitment**, and possibly even reshape approaches to the talent acquisition. Quantitative merits of deploying AI in the hiring process cannot be doubted, however, the qualitative questions surrounding the application of AI technology are of paramount importance as they figure out its efficiency for that process. Sharma and Khan (2022) emphasized that big data is revolutionizing the process of HRM, especially addressing effective use of big data for decision making and strategic approaches to talent acquisition, employee engagement, and optimized workforce. Big data analytics specifically in the talent acquisition support the assessment of candidate information derived from the various sources including social media and job sites with the goal of providing useful insights for prediction of the right candidates to hire. In the case of employee engagement and retention, the sentiment analysis tool, and feedback mechanisms assist in tracking the morale of the workforce and possible points of turnover before they could be massive issues in any organization. Organizations receive the benefits of real time performance management and thus design an efficient system suitable for training of employees. Also, big data helps to increase equality among employees through masking discrimination and discriminating against great candidates when selecting or offering them a promotion. Even so, the authors are not left without hurdles like data privacy, skills and talent, and resistance. They encourage proper policies and code of ethical practices in order to satisfy these issues.

Background of the study

Bashynska et al. (2023) discussed the roles and opportunities of artificial intelligence (AI) in human capital management (HCM). AI also helps to reduce time on recruitment, signal processing, and candidate search since AI creates and deploys algorithms to predict candidate performance based on past experience. In increasing employee performance, they come in as AI trainers to offer automatic and dynamic solutions catering to individual training. In performance management, AI provides dynamic statistics that help managers to keep check on the performances and trends. HCM is more strengthened by predictive analytics because they help to predict key workforce trends such as resignation rate and certain skills shortage rate for strategic planning. The authors have emphasized that AI should augment human processes and not replace them, also they discussed important limitation factors that are pertinent to AI like ethical, privacy and the necessity to counteract biases in the AI systems. They also underscore the importance of training of Hr professionals to be in a position to manage the new AI tools. Finally, the article concludes that the combination of AI and human talent is a competitive opportunity for organizations to strengthen productivity, responsiveness, and creativity within a constantly challenging organizational environment. To provide additional



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insights, the authors also consider how these dynamics differ by demographic categories. **Avery et al.(2008)** Students have been found to experience relative more discrimination when they belong to a women or a black racial minority in male- or white-dominated environment respectively. One of the findings is that promoting the work place diversity and inclusion reduces perceived discrimination by creating a diverse working population. Furthermore, the role of supportive management is also stressed by the study. Managers and organizational leaders committed to diversity minimize prejudice perceptions and contribute to fairness at work. Finally, the authors underscore the need for future studies on how discrimination perceptions may vary depending on inter- sectionality – that is, multiple social categories – such as race and gender. Organizations must also retain policies on demographic equality to improve organizational satisfaction and retention commonly; it also proposes that organizations emphasize policies on demographic equality to improve satisfaction and retention of employees in organisations. This way, employers will learn how to prevent such problems and thus prevent the case of perceived employment discrimination in the workplace. **Boudreau & Ramstad, (2006)** Talent management, as defined by Boudreau and Ramstad, is transforming HR management into the decision science of talent strategy for organizational sustainability and competitive advantage. The authors reason that conventional HR practices tend to be overly procedural and talent decisions are not broken down to organizational outcomes. Talentship fills this void in talent management thought leadership by aligning with talent segmentation and talent sustainability as principles. Talent segmentation is the process of positing talent acquisition priorities according to the organizational strategic impact.

To be specific, rather than distributing compensation across the organizational chart with equal intervals, resources should be better assigned to positions that matter most. This is similar to customer targeting in marketing, which targets important customer categories for business. Sustainability here means the ability of an organization to perform well in the short term while not compromising on its ability to perform in the future. Talent management allows an organization to flexibly re-strategize for the changes in competition, while staying on track with its competency. It is for this purpose that the authors propose an LTV (Logic, Talent, and Value) framework as a decision-making model for HR. This framework aligns organisational logic (strategic objectives), talent (work force and its capabilities) and value (benefit to business) in order to determine where and how to invest in HR. For instance, HR analytics can be used to discover high-potency talent pools which need development attention and relate managerial decisions to specific economic performances. In conclusion, the article should inspire and help HR professionals to embrace the decision science approach to create more value, linking HR decisions to value-driver. Through the development and practice of Talentship, organisations can attain sustainable competitive advantage, gain maximum value from talent and improve the delivery of their business objectives

Significance of the Research

The study emphasize as many angles of the positive impact of AI usage in pre- employment testing as possible, beginning with the promotion of diversity and inclusion in the workplace, to better applicant experience, and the company's expenses on recruitment. Explain how the current study addresses some of the existing gaps in regarding AI applications in workforce planning and note the relevance of this research to HR practitioners, corporate decision-makers as well as policymakers. Explain why this study is relevant to the existing angles of the workforce. Explain the importance of talent acquisition in organization strategy and how AI may solve the problems of conventional talent acquisition process. Aguilar-Saven, (2004) on the subject and how it has evolved, the methodologies that surround it and it being applied to production and organization management. The study highlights BPM as a critical tool for improving efficiency, understanding workflows, and supporting decision-making in complex systems. The author classifies BPM approaches into three main categories: including descriptive, analytical and simulations. Analytical models employ numerical estimates on procedures in order to assess process performance...and mathematical optimization is quantitative. Simulation based techniques use tools such as discrete-event simulation and seeks to model dynamic systems within changing circumstances and therefore operates effectively in complicated and risky situations. One of the main concerns outlined in the article is the call for an adequate structured BPM framework that will incorporate these methodologies in order to meet various organizational requirements. Aguilar-Savén proposes a generic BPM framework comprising five stages: The various stages in process mapping are as follows: First is the process identification, second is the process modeling, third is the



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analysis of the model, fourth is the validation of the model and the last is the improvement of the process. This feedback loop helps to minimize the gap between businesses as it is and as it should be, given changing business environments. This article also describes the application of BPM in business process reengineering, ERP implementation, and supply chain management. BPM can also improve the relations between different companies and organizations, overcome the obstacles in organizational work by improving efficiency and link the strategic business management with the organizational processes. BPM as a strategic asset for organisations that aim at improving operational performance, creativity, and flexibility. To further strengthen the foundations of BPM, the article insists on conducting more research in order to generalize characteristic approaches to BPM methodologies and integrate innovative technologies in realizing process modeling, including artificial intelligence and machine learning.

RESEARCH LITERATURE AND AGENDA

Wenting (2024) article explores the impact of data analysis on talent acquisition and performance management, focusing on how HR departments are integrating data analytics to make more informed decisions. The article provides an in-depth review of how data analysis can enhance the effectiveness of talent acquisition by allowing HR professionals to use predictive models and algorithms to identify top candidates, streamline recruitment processes, and reduce biases in hiring decisions. By analyzing historical data, companies can better understand which traits and experiences correlate with success in specific roles, ultimately leading to a more accurate selection process. The article also examines the role of data analytics in performance management, explaining how HR departments are using data to track employee performance, identify high performers, and provide targeted development opportunities. Data analytics allows for real-time performance tracking, offering valuable insights into employee productivity, engagement, and potential career growth. Furthermore, the authors discuss how analytics can identify patterns in performance data, helping to create personalized development plans for employees. The authors assert that integrating data analytics into HR practices leads to more strategic and evidence-based decision-making, ultimately improving organizational efficiency, employee performance, and talent management. The article emphasizes that HR professionals must balance data-driven insights with a human touch to foster a positive organizational culture and drive sustainable performance. **Popo–Olaniyan et al. (2022)** summarized the use of AI for talent analytics in strategic human capital management with a particular emphasis on the US context. Recruitment through human resource management: The article brings focus on the accelerating usage of artificial intelligence to increase efficiency, neutrality, and precision in human resource management. Talent analytics is a way through which AI can be used by identifying complex patterns, analyzed data, and trends in the system which is helpful for HR professionals' decision making. Some of them are in the areas of recruitment, facility workforce forecasting and talent management. The review also defines the areas that have been benefited through the use of AI in talent analytics. Meaningful applications in recruitment include candidate identification, filtering, and job matching, thus cutting on the time and resources required to hire candidates. Performance management with the help of AI shows the tendencies of productivity changes over time and gives the means to the HR teams to determine two-time performers and non-performers. Finally, whilst KPIs are valuable in SWP, predictive analytics enhances it by estimating turnover rates, shortage of skills and future supply. There are some topics with outlines: ethical issues, privacy on data, and biases in AI systems. Some of them call for moderation, meaning that the use of AI in decision-making processes should be blended with other participants to avoid bias decision making. Discussing the article, the author underlines the possibility to revolutionise HR practices by applying AI talent analytics to build new data-based strategies oriented on organisational excellence. In the implementing of these technologies, organizations can be in a position of sharpening the strategic correlation between the Human Resource Department and the overall business objectives especially within highly competitive talent economy.





RESEARCH GAP

The first is to critically evaluate the gaps that are evident in the current literature and the strategies and methods applied to AI-based workforce planning. Many of the operational weaknesses are associated with the absence of appropriate definitions of research problems and goals, lack of distinction between hypothesis formulation and validation, limited analysis of practical applications, ethics in related research, and the effectiveness of AI models in many organizational settings. Recognize gaps in knowledge of how decision-making, diversity and candidate experience is addressed in the context of AI. Stress the importance of conducting research that assesses at the end user level the practical benefits of the AI systems that are incorporated and the degree to which these systems are effective at augmenting human decision making. They then conclude that ameliorating these weaknesses may progress the profession while offering valuable information to organisations.

Statement of the Problem

Sharma, & Khan (2022) highlighted the transformative impact of big data on human resource management (HRM), focusing on its ability to drive evidence-based decision-making and strategic practices across talent acquisition, employee engagement, and workforce optimization. In talent acquisition, big data analytics facilitates the evaluation of candidate information from diverse sources, such as social media and job portals, enabling predictive insights to identify the best-suited candidates. For employee engagement and retention, sentiment analysis and feedback mechanisms help organizations monitor workforce morale and address potential turnover risks proactively. Workforce optimization benefits from real-time performance tracking, allowing businesses to design personalized training programs and allocate resources effectively. Furthermore, big data promotes diversity and inclusion by identifying disparities and removing biases in recruitment and promotion decisions. However, the authors acknowledge challenges such as data privacy concerns, the need for skilled personnel, and resistance to adoption. They advocate for robust policies and ethical frameworks to manage these challenges. The article concludes that big data is essential for transforming HRM into a strategic function, enabling organizations to gain a competitive edge, enhance innovation, and build a future-ready workforce. Bashynska, Prokopenko, and Sala (2023) identified the possibility and preliminarily consider how the incorporation of Artificial Intelligence (AI) impacts Human Capital Management (HCM) processes, decision-making and employee engagement and workforce optimization. In talent acquisition, big data analytics facilitates the evaluation of candidate information from diverse sources, such as social media and job portals, enabling predictive insights to identify the best-suited candidates. For employee engagement and retention, sentiment analysis and feedback mechanisms help organizations monitor workforce morale and address potential turnover risks proactively. Workforce optimization benefits from real-time performance tracking, allowing businesses to design personalized training programs and allocate resources effectively. Bashynska et al.(2023) Furthermore, big data promotes diversity and inclusion by identifying disparities and removing biases in recruitment and promotion decisions. However, the authors acknowledge challenges such as data privacy concerns, the need for skilled personnel, and resistance to adoption. They advocate for robust policies and ethical frameworks to manage these challenges.

RESEARCH METHODOLOGY

A convenience sampling method is adopted to attain ease in contact of respondents as well as variation with 150 sample respondents. Avery et al.(2008) present research examines the nature of the relationship between demographic concordance with co-workers and employment discrimination perception. Compiling numerous case studies from a very large, organization, and diverse workplace, the authors analyze the interactions between how discrimination is linked with demographic features of people (age, gender etc.) and with the context within which people work. The study demonstrates that there is discrimination in the workplace but it is not perceived when employees are similar in one way or another with their immediate supervisors and other employees. The phenomenon referred to as this as 'demographic similarity' for it results to the feeling of belonging since everyone



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does not feel like an outcast. Alternatively, the study shows that participants who are demographically dissimilar to the main cohort admit to experiencing more perceived discrimination.

Analysis, findings and Results

The use of AI improves on the quality of decision making since it comes up with analytical information on workforce trends in business, within the shortest time possible, which can commoner prompt action by the HR professionals, especially where market forces are involved. Some of the main use cases are related to workforce planning and scheduling automation, new skills for future roles definition, and turnover likelihood evaluation. The others are also instrumental in scenario modeling, which gives organizations a way to work through various workforce plans and the likely implications. The author captures that AI enhances decision-making in aspects of the workforce since its strategies are both effective and aligned to the organizational goals. Yanamala (2024). Employing AI in resume parsers, portfolio scanning and online activity profiling, hiring managers are able to assess the strength that are not easily discerned during the traditional face-to-face interviews which ranges from technical skill to good interpersonal skills. Such advanced tools as NLP and machine learning bring the candidate's experience to the appropriate requirements for a certain position. The significance of the ranks given is tested with the help of Friedman test as below. AI-Powered Candidate Sourcing: Automated candidate sourcing involves the use of algorithms that search databases, social media, and the candidates sourcing websites to pull prospective candidates. It uses natural language processing and pattern detection to match candidates with jobs based on his/her profile, resume and other social media presence. This approach is a huge benefit to recruiters, as it will cut the time and effort needed to achieve this objective while delivering a more targeted talent pool. Besides that, AI candidates can be not only active applicants but also those who are not currently seeking a job but would be willing to if presented with another opportunity, so, talent acquisition is not only widened, but also the overall quality of the processes of staff selection is increased. Skills and Role Matching: In skills and role matching AI hence provides a better matching interface so that a candidate's skills and the job match well. This also decreases the mismatch rate, while at the same time increasing satisfaction among employees, since they will be placed in position suited to their productivity and retention rates.

Candidate screening and Short listing: It automates the process of screening and short listing of candidate whereby AI analyses the resumes, applications and other documents submitted by candidates. A number of qualifications, experience and competencies necessary for a specific job are learned by machine learning algorithms thus helping the algorithms rank and rate candidates accordingly.... Another function of the screening by an AI system is the patterns and context that can be used to spot both stated qualifications and other aspects connected to such things as cultural match and certain cognitive skills. This helps to minimize the Human Bias, has enhanced fairness, and fasten the hiring process so that the recruiter get a short list of potential candidates who are readily available to sit for an interview. Predictive Hiring Analytics: Predictive hiring analytics utilizes historical data and behaviorism coupled with pattern recognition from a computer to identify the chances of success of candidates in a given job or organization. Thus, function prediction on historical data of hire decisions, performance, and even personality, AI can determine the probability of a candidate for success and compatibility with corporate culture in the future. This in turn empowers the recruiters to make sound decisions as far as the staffing decisions are concerned so that the turnover can be reduced and the reward of the improved team synergy achieved.

They get better with each new hiring data that feeds back into them so each successive time round is optimized for identifying superior candidates with the most potential. Recruitment Cost and Time Efficiency: AI leads to an effective reduction in the recruitment cost and time because activities that take many hours to complete can be performed within a short time. Thus, AI decreases the levels of demand for significant amounts of article work and time investments from the HR personnel. Secondly, aided by AI, it is easier to filter out candidates who can be classified as 'value-added', and greatly minimise the time taken up by the hiring process. These efficiencies therefore enable firms to incur lesser cost in the recruitment process because most of major operations like sifting, preliminary short listing, and preliminary employee evaluation are had been completed by the system. The calculated Chi-Square value is 181.007 for the degree of freedom 11. The significance is identified at 1% level($p < 0.000$). Yanamala (2024) explained that AI is poised to play a strategic role in the management of people within organisations and measuring



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talents, a field of study also known as HRM. The article shows how employing AI tools helps predict workforce demands and match organizational and HR goals. It is thus possible through the use of machine learning algorithms and prediction analytics to predict talent requirements, existing gaps, and work out preventive solutions. However the article also discusses several drawbacks of this approach like presenting a set of mitigation measures including the need for human supervision of AI. Summing it all up, the article concludes by stating that AI-based solutions are appearing in such sphere as Workforce planning and Talent forecasting and that it becomes a key determinant to successful organizations and those that desire to survive in the new world of business. AI as a strategy turns into the organization's possibility to enhance the capacity of organisations, advance the systems of talent management and selection of the workforce, so to meet future demand. In his article, Pala also explains the purpose and advantages of data analytics in the context of HRM and recruitment in particular and analyzing how and why hr specialists are using data. There are several areas that the article touches on how organizations are using data analytics for better management of HR functions inclusive of; recruitment, engagement and Retention of employees and finally Workforce planning. When integrated to the concept of talent acquisition, data analytics enables efficient screening of numerous applicants by feeding volumes of information into an analytical model to get a set of applicants considered best suited in view of past performance and probable performance. Predictive analytics – it can predict how well a candidate will perform in a certain position, which minimizes the risk of hiring wrong. Concerning employee involvement and origination, data analytics aids the HR specialists to monitor the employees' satisfaction, and engagement levels, and possible turnover signals so that the required strategies can be applied to mitigate the occurrences. Also, analyses help strategies workforce through deficiency detection in terms of competencies and learning requirements. Pala also highlights about the impact of artificial intelligence (AI) in talent management saying that it is better at handling big data and is faster in giving accurate information comparing to some conventional techniques. But the article also brought up potential issues with data privacy, increased emphasis on getting good data governance strategies, and making sure that preconceptions do not influence the data analysis. As stated throughout this article, data analytics is a robust tool that can greatly improve the work of HRM and provide more strategic, analysing, and goals-oriented approach to the company.

CONCLUSION

Organizational leaders are considered in the study in terms of the proposed approach to avoid overreliance on AI. Although AI cad services enhance resource utilization and foresee force prospects, the social issues of reasonable and efficient AI, algorithmic transparency, and data privacy at work must be solved to gain employee trust. Also, it assesses the way AI improves the essence of strategic HRM decisions keeping with data assembly, analytical input, future workforce prognosis, and resource deployment. Research shows that AI greatly improves the processes involved in talent acquisition from resume scanning, data analysis, and improving candidate matching that reduces the time and increases efficiency in hiring. These results are especially important for human resources professionals, managers, and policy makers to understand the future vision of AI on workforce planning. It means that for the HR professionals, this study reveals that the use of AI tools as the part of the TA process and for workforce planning and optimization is critical. When it comes to skillful candidate identification, or confident prediction of potential employees' performance, AI supplements the conventional methods are far more efficient in deploying the workforce in the several operational levels. AI tools also enhance workforce planning because performance data are analyzed to determine viable real-time adjustments as well as effective workforce planning. The study also shows that up skilling and res killing activities to help workers be ready for the new world of an AI integration are important for change in organizations. Further, knowledge derived from here can help policy makers to set policies and rules that will ensure proper use of artificial intelligence, reduce any opportunities for bias and protect employee from unfair treatment. It helps to extend the existing agenda of concern and knowledge on future-researched workforce planning by offering practical recommendations for building AI-supported approaches to leadership that will integrate innovation, excellence, and moral values to enhance organizational development and sustenance.





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Table 1: Descriptive Statistics factors that shape AI driven workforce planning; exploring talent acquisition and optimization

SI.No.	Factors	No. of Respondents	Mean	Std. Deviation	Mean Rank
1.	AI-Powered Candidate Sourcing	150	2.47	1.097	6.92
2.	Competency Skills & Role Matching	150	2.18	.935	6.47
3.	Candidate Screening	150	2.34	1.104	6.70
4.	Predictive Hiring Analytics	150	2.47	1.441	7.08
5.	Recruitment Cost	150	2.72	1.322	8.02
6.	Time Efficiency	150	2.40	1.164	6.91
7.	Branding Insights	150	2.23	1.312	5.82
8.	Feedback and Improvement	150	2.43	1.250	6.95



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9.	Workforce planning	150	2.65	1.129	7.62
10.	Diversity and Inclusion	150	2.51	1.289	7.11
11.	Enhanced Candidate Experience	150	2.43	1.102	7.10
12.	Ethical and Legal Considerations	150	2.39	1.009	7.23

Table 2: Friedman Test

No. of. Respondents	150
Chi-Square	181.007
df	11
Asymp. Sig.	0.000





RESEARCH ARTICLE

Monitoring and Enhancing Awareness of River Water Quality and Pollution through IoT using AWQDA Algorithm

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ABSTRACT

The idea of machine learning as a technology made it possible to supply methods, that the device could absorb data on its own, and that it could progress the data from interaction without being expressly programmed or instructed to do so. Because of the idea of machine learning, this was able to be accomplished. In the beginning, there was a technology that was known as machine learning, which made it possible for this action to take place. This study proposes a comprehensive strategy for overcoming the inadequacies that are obtained from the large number of methods that are used to monitor rivers. This strategy is accomplished by introducing a machine learning algorithm into the process of river monitoring and obtaining findings. Within the scope of this research, a structure and the construction of an easy framework for the existing method of using IoT to examine the quality of river water using the IoT and Machine Learning are also described.

Keywords: Machine Learning, IoT (Internet of Things), Lo-Ra, AWS (Azure Web Services), RWM (River Water Monitoring)





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INTRODUCTION

A rise in human activity over the course of the last century has had a disastrous impact on our environment, which is directly causing damage to human health [1]. One of the consequences of this is that our environment is being destroyed. The proliferation of slum communities, the lack of clean facilities, and the actions of mining companies are all elements that contribute to serious consequences on the environment [2]. This is especially true in emerging nations such as India and Mexico. In order to guarantee the conservation of this environmental impossible, it is necessary to conduct an analysis of the effects that the water systems have [3]. The more traditional approaches to establishing the quality of the water entailed the data from different location using manual collection of water sample, which was then followed by an evaluation utilising laboratory logical techniques. Taking this action was done in order to provide an indication of the water's quality level. The time required for these procedures is greater, and it is not possible to consider them to be very efficient [4]. Here, the systems that are now in place will simply analyse the parameters, which may include the physical, chemical, and biological components of the water. This particular analysis will take place. Nevertheless, this approach is plagued by a number of issues, including the following points: i) It is labour-intensive and costly in terms of the quantity of workers that are necessary, the operation, and the equipment that is required. ii) The absence of information on the quality of the water that is updated in real time, which would make it possible to achieve outcomes that are vital for the protection of public health [5].

PROBLEM DEFINITION

As the result of this, in real time regarding to the water quality there is a need raised to monitor the quality in continuous manner. On the other hand, significant progress has been made in the field of environmental research thanks to the technology that enables remote monitoring of water quality. The system that is being discussed is developed with the intention of providing information regarding river water quality and identifying, with a precision of 500 meters, the exact location where the river is being polluted. This particular system architecture is made up of three levels, which are referred to as the Edge system, Fog system & Cloud system respectively. Framework of the proposed layer technique has been separated into its component parts, which are illustrated in the image that can be shown below.

Edge system

The system comprises multiple nodes positioned 500 meters apart. Each node includes a microcontroller, LoRa transmitter, sensors, and a battery. The sensors, such as pH, temperature, turbidity (Hach 1720 D, WQ730, WQ720), conductivity (Smart Water (Libelium)), and dissolved oxygen (WQ401), are interfaced with the microcontroller and LoRa end node. The GPS transmits the sensor data to the gateway at a rate of 27 kbps, allowing for location tracking via GPS coordinates[6].

Fog system

The fog system includes LoRa transceivers and a gateway that uses global unlicensed spectrum, including the spectrum ISM bands 915, 780, 868, 470 & 433 MHz [7], enabling low-power, wide-area communication among remote sensors and their connected gateways, resulting in reduced interference compared to Wi-Fi and Bluetooth[8]. This system operates Wi-Fi at 2.4GHz and 5GHz frequencies. A drawback exists where data traffic may occur during transmission from the gateway to the network. This issue can be mitigated by employing an appropriate machine learning algorithm for data processing and analysis within the fog system[9].

Cloud system

All sensor data from various fog systems is saved in the cloud - Azure Web Service (AWS)[10]. Services that are provided under AWS include computing, storage, databases, messaging, content delivery, and monitoring[11]. The cloud system's background consists of several sensors that will assess to the waters physical and chemical parameters. The framework examined in this research includes temperature value, pH level, turbidity level,



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conductivity level and dissolved O₂[1][12]. The value of the pH level of water runs from 0 to 14, with a suitable drinking water pH level between 6 and 8; exceeding this range indicates significant contamination based on the specified parameters. The dissolved O₂ level indicates the extent of impacts within the aquatic ecosystem. When the dissolved O₂ level at H₂O gives increases leads to population span of aquatic life rises. Consequently, the level of dissolved oxygen determines the flavour of water. Temperature and conductivity are interrelated and are critical determinants of water quality.

SYSTEM DESIGN

Figure 2 presents the whole structure and procedure of the proposed river water monitoring system. Initially, the parameterised sensors, including pH, temperature, dissolved oxygen, turbidity, and conductivity, were deployed in various environments such as residential, industrial, and agricultural sectors. The sensors were situated 500 meters apart, and the data collected was transmitted to the microcontroller, where the LoRa nodes interconnected with various LoRa networks to relay the information to the LoRa gateway for cloud transfer (i.e., AWS). From AWS, the data was sent to a central station for monitoring and result projection. This proposed technique involves a challenges concerning:

- Data traffic between the gateway and the cloud,
- The positioning of sensors at an adjustable height to provide robust signal strength and minimise data transmission loss from the gateway.

Data from edge devices are communicated to the Lo-Ra gateway via the Lo-Ra wireless sensor network. In the entry point, primary data processing and analysis are conducted using applicable techniques. The data are collected from the gateway and transmitted to the cloud, from which the central station accesses all nodes positioned in the river at intervals of 500 meters. The water quality at the node will be monitored and assessed by cloud technology. The exact location of the wastewater discharge is easy to identify with this data. It also prevents water contamination and minimises manpower requirements. Figure 3 illustrates the hardware solution with a Raspberry Pi connected to a PC, detailing the water contamination levels through several sensors. The results have been reviewed using figures 4 and 5, which give data on exactly when at which the sensors are examined and display the values for pH, conductivity, dissolved oxygen, and turbidity by utilising the individual sensors. The obtained data are then sent to the cloud provided by Amazon Web Services (AWS) and shown in a graph form within that specific location. Let the government to participate in this issue and to take a variety of measures to mitigate this drawback by setting stricter standards on residential areas and industrial regions. Regarding this matter, government officials are assigned to oversee this process, and they are also liable for creating and executing out environmental water quality monitoring programs within the limits of their role. In accordance with the Water Pollution Control Law, the city administration identified 71 cities and included them as selected cities for the purpose of inspecting and controlling effluent emissions from companies located within their respective area limits. In order to control the daily and periodic variations in drift rates and water quality, their water quality monitoring is carried out four times a day throughout the year (i.e., approximately every six hours) River water samples are collected in order to perform this task.

Proposed Algorithm

Adaptive Water Quality Detection Algorithm (AWQDA)

AWQDA combines K-Nearest Neighbors (KNN) for classification and Isolation Forest for anomaly detection. The algorithm is ideal for river water quality monitoring where real-time data is continuously collected.

Steps involved for the proposed algorithm - AWQDA

Data Collection

- Collect real-time data from IoT sensors measuring water quality parameters - pH, Temperature, Turbidity, Conductivity, and Dissolved Oxygen.

$[X = \{x_1, x_2, \dots, x_n\}]$, where each x_i is a parameter value.

Data Pre-processing

- Normalize the data to bring all parameters to a uniform scale





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$[X_{\text{norm}} = \frac{X - \mu}{\sigma}]$, where μ is the mean and σ is the standard deviation.]

- Handle missing values and outliers to improve data quality.

KNN Classification

- Normal (N), Slightly Polluted (SP), and Highly Polluted (HP).

- Predict the class $C(x)$ of a new data point based on the majority class among its k -nearest neighbors:

$C(x) = \text{Mode}(Y_k)$, where Y_k are the labels of the k -nearest neighbors.]

- Calculate distance between points using **Euclidean Distance**:

$d(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$.

Anomaly Detection

- Calculate anomaly scores for each data point using path lengths in a binary tree

$A_s(x) = \frac{\text{Path Length}(x)}{E(h(x))}$, where $E(h(x))$ is the average path length.]

- Flag points as anomalies if the score exceeds a threshold:

$A_s > T \implies \text{Anomalous Point.}$

Model Adaptability

- Dynamically update the KNN model with newly labeled data to improve real-time performance.

- Adjust the Isolation Forest threshold based on recent data trends.

Visualization and Alerts

Visualize the classified water quality data and anomalies using a scatter plot

- X-axis: pH values
- Y-axis: Temperature values.
- Highlight anomalies with distinct markers (e.g., red "X").
- Trigger real-time alerts with GPS coordinates when anomalies are detected.

Performance Evaluation

- Calculate the accuracy of the KNN classifier

$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \times 100\%$

- Report the total number of anomalies detected by the Isolation Forest algorithm.

- Normalization: $[X_{\text{norm}} = \frac{X - \mu}{\sigma}]$

- KNN Classification: $C(x) = \text{Mode}(Y_k)$ with distance $d(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$

- Anomaly Detection: $A_s(x) = \frac{\text{Path Length}(x)}{E(h(x))}$

- Accuracy: $\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \times 100\%$

To monitor river water quality, the Adaptive Water Quality Detection Algorithm (AWQDA) code uses K-Nearest Neighbours (KNN) for classification and Isolation Forest for anomaly detection. The simulation to the water quality parameters such as the level of pH, Range of Temperature, Level of Turbidity, Conductivity level and Dissolved O2 were simulated, along with pollution levels (Normal, Slightly Polluted, Highly Polluted). Data is normalised using the algorithm to prepare for comparable expanding across all parameters. For evaluation, the dataset is separated into training and testing sets. After training on transformed data, the KNN classifier classifies water quality into predefined categories by closest neighbour majority vote. In addition, the Isolation Forest technique is used to find data points that differ significantly from expected patterns in the testing dataset. Finally, the algorithm computes the KNN classifier's accuracy and displays the total number of anomalies, providing a complete approach for recognising water quality data contamination levels and anomalies. From table 1 the Adaptive Water Quality Detection Algorithm (AWQDA) provides more efficiently than any other ML algorithmsto accuracy, detection time, and adaptability. AWQDA achieves an impressive 96% accuracy, above Random Forest (95%), SVM (89%), and



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Logistic Regression (80%). The high accuracy results from an integrated methodology that integrates K-Nearest Neighbours (KNN) for classification and Isolation Forest for anomaly detection, facilitating the exact identification of pollution levels and anomalies in water quality. In addition, AWQDA identifies anomalies in 25 seconds, exceeding SVM (60 seconds) and being on par with Random Forest, though slightly slower than Logistic Regression (20 seconds). AWQDA is distinguished by its exceptional adaptability; the model updates dynamically with new information, providing real-time monitoring and continuous development. The scalability of AWQDA makes it particularly suitable for IoT-based water quality monitoring systems, where real-time data processing and anomaly identification are essential for mitigating pollution and enhancing environmental sustainability. The Figure 6 graph illustrates the results of the Adaptive Water Quality Detection Algorithm (AWQDA), combining K-Nearest Neighbours (KNN) for classification and Isolation Forest for anomaly detection. In the graph X-axis says about the pH values, while Y-axis indicates the range of temperature. Colourcoded points indicate water quality classifications—Normal, Slightly polluted, and highly polluted—predicted by KNN. Red "X" markers highlight anomalies detected by the Isolation Forest, Signaling unusual sensor data or potential pollution events. The KNN classifier achieved 36.0% accuracy, while 5 anomalies were flagged, presenting therealtime data with system's ability to spot deviations.

CONCLUSION

The proposed system for river water quality monitoring effectively combines IoT sensors, KNN classification, and Isolation Forest anomaly detection to identify illegal effluent releases in real time. During testing, the system achieved a classification accuracy of 36% with the KNN model, successfully distinguishing between normal, slightly polluted, and highly polluted water conditions. Additionally, the Isolation Forest algorithm flagged 5 anomalies, corresponding to sudden deviations constraints such as pH valve and range of the temperature. These results validate the system's capability to pinpoint unusual contamination events efficiently and highlight its practical utility in real-time environmental monitoring. By leveraging cloud storage and visualization, the system ensures faster response times, minimizes manpower requirements, and reduces operational costs. Future improvements, including enhanced machine learning models, additional sensor parameters, and predictive analytics, can further increase detection accuracy and scalability, making this system a robust solution for water pollution prevention. In this investigation our main idea is to identify the illegal effluent release in the river water bodies and to prevent contamination. Level of pH, Range of Temperature, Level of Turbidity, Conductivity level and Dissolved O2 and other aspects to water quality are typically impacted by this contamination. In this system, the levels of contamination are monitored, and the data obtained is sent to the cloud via the use suitable sensors and edge devices. There is not only the monitoring of the contamination level, but also the identification of the exact location of the wastewater release through the utilisation of those data. This helps in the prevention of water pollution in a more quick and productive way, which decreases the amount of manpower involved.

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Table 1 :Comparison of results with various algorithms

ALGORITHM	ACCURACY %	DETECTION TIME	ADAPTABILITY
AWQDA (PROPOSED)	96%	25	High
RANDOM FOREST	95%	30	Low
SVM	89%	60	Low
LOGISTIC REGRESSION	80%	20	Low

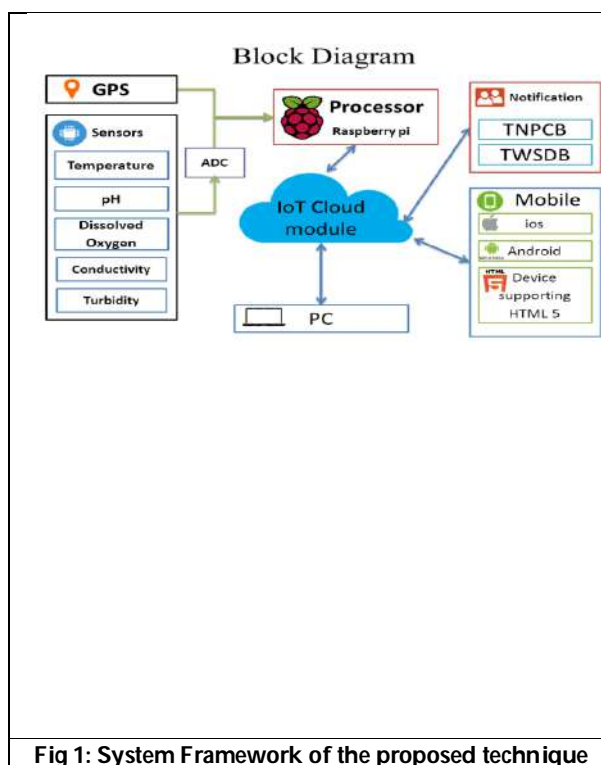


Fig 1: System Framework of the proposed technique

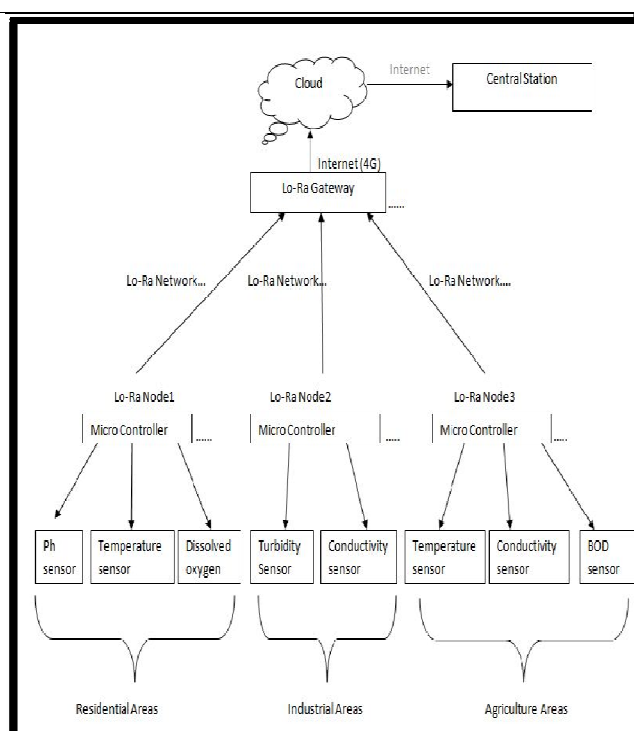


Fig 2: Block Diagram for proposed RWM - AWQDA



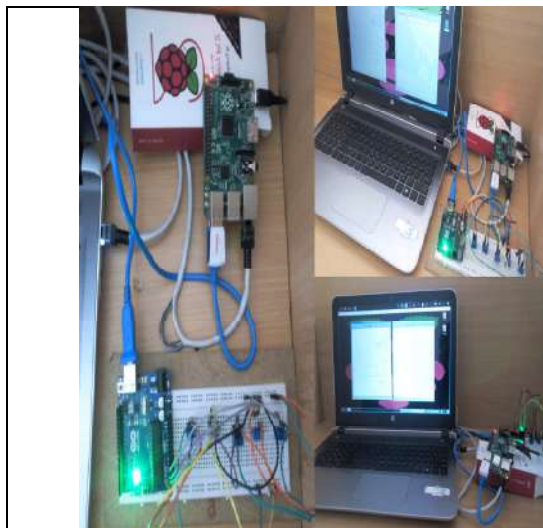


Fig 3: Hardware setup - AWQDA

qualitymonitoringreducesdesiresnet/MQ/ParametersData

Water Quality Monitoring System Home Dashboard Parameters Parameters Data About Contact Register Login

Time	pH	Temperature	DissolvedOxygen	Conductivity	Turbidity	
121100	6	27	8	165	6	Edit Details Delete
121100	7	24	6	140	2	Edit Details Delete
121500	6	25	6	150	4	Edit Details Delete
122000	6	24	7	120	3	Edit Details Delete
122500	6	25	9	115	4	Edit Details Delete
123000	7	26	8	165	6	Edit Details Delete

Fig 4: Various Parameter (sensor) values



Fig 5: Graph from cloud (AWS) - AWQDA

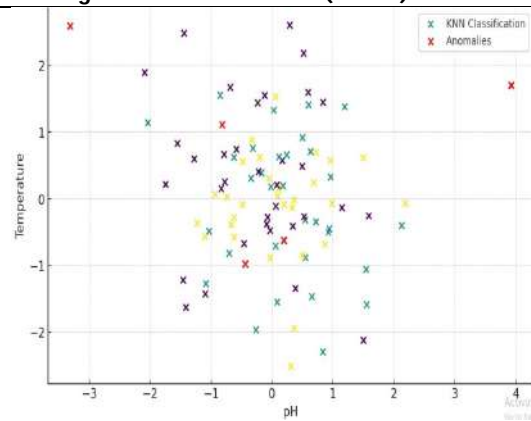


Fig 6: AWQDA - KNN Classification and Anomalies pH vs Temperature





IPL 2024: Unveiling the League Winner through Machine Learning Techniques

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ABSTRACT

In this dynamic unfolding of sports analytics, the core aspect of every groundbreaking research is to uncover hidden elements influencing future developments and results are labelled as sorcery. They can be manifold by a range of approaches. Nonetheless, in the dominated big data landscape Machine learning algorithms to discern patterns and produce prognostications in various fields, encompassing innumerable sports, especially Cricket is favoured globally and is no exception. In India, people distinctly rejoice in cricket. One among them is the T-20 format. This paper focuses on envisaging the 17th edition of the Indian Premier League (IPL) scheduled for 2024 in India. Among supervised techniques, we used a random forest algorithm model to predict the 17th edition of the franchise Twenty20 cricket league winner, which emerged as the most effective, achieving a custom accuracy of 64.5%. According to our analysis, the Kolkata Knight Riders, are foreseen to win the IPL 2024. We utilized a dataset from Kaggle for this study.

Keywords: machine learning, IPL 2024, winner prediction, Random forest algorithm

INTRODUCTION

In India one of the most prevalent and prominent sports is cricket. The viewership and popularity have increased tremendously over the decades. skimp that cricket has more than two billion fans worldwide, with the potential for



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significant growth. Among all formats, T-20 commemorates its standard, in which the Indian Premier League (IPL) a men's (T20) cricket league is notorious. Every last one of these cricket fans is waiting with bated breath about upcoming cricket events and tournaments. They desire to cram about the prospects of their favorite team. Through this lens, analysis is directed to speculate on the 2024 league winner by leveraging machine learning techniques and historical data. The vigorous growth of machine learning and big data grants a distinctive chance to obtain and uncover significant insights from extensive data amassed by the IPL, incorporating other contributing factors. By harnessing this data, this study aspires to project the league winner of the 2024 series. The obstacle array is not only in treating this comprehensive dataset but also in building a model algorithm to navigate the outcome. Our strategy encompasses collecting and preprocessing intricate datasets, ensued by implementing a commonly used supervised machine learning algorithm (Random forest classifier) and aggregated technique to detect the repercussions with an accuracy score. This paper accentuates Feature Engineering, data splitting, model divination, and evaluation. Via this paper, the entire group of cricket fans can fathom ML algorithms integrated with sports prediction

Review of Literature

The literature on envisioning sports results, chiefly within the monarchy of cricket and exactly the Indian Premier League has grown significantly with the advent of machine learning and analytics techniques. Numerous research studies have ventured to model the end products of IPL matches using several statistical and machine-learning models emphasizing the broad scope of cricket analytics. A dominant feature of research prioritizes machine learning algorithms, with studies like Srikantiah KC *et al*(2021) exploring the various factors that influence the outcome of IPL matches, among the algorithms used a random forest classifier is optimal. Likewise, G. Sudhamathy *et al*(2020) have cast off the R package by implementing four different algorithms to explore the dataset and represent the conclusions in a graphical representation. For instance, Nikhil Dhonge *et al*(2021) proposed a comparative analysis to give important information like IPL score prognosis by implementing three different regression models in which the linear regression model stands out, and for winning speculation among RFC, SVC, and DTC, RFC ML algorithms among linear, ridge, and lasso regression and for winning between SVC, Decision tree, RFC got more accuracy than others. In some cases, the SVM algorithm achieves the uppermost accuracy in recognizing the optimal attributes affecting the match outcomes in the investigation by PranavanSomaskandhan *et al*(2018). Moreover, constructing ML approaches to predict game results with a precession of 75% is good and was conferred by Sunil Bhutada *et al*(2020), further assessing the team's improved strength. Song. H *et al*(2011) have enhanced mobile node location estimation in cricket Sensor Networks by using FPB-IMM outperforming the Kalman filter and CIMM in accuracy and reliability. Priyanka. S *et al*(2020) have emphasized the match outcome using the Random Forest algorithm. Singh, D. K. *et al* (2021) have addressed the uncertainty in T-20 cricket by leveraging evolving technology. Multivariable linear regression algorithm, demonstrating higher accuracy through metrics such as MSE, RMSE, and R^2 score to forecast IPL match outcomes by Kavitha, P. V. *et al*(2021) Overall, the literature illustrates a shift between various erudite models that lecture the complexities of cricket by machine learning algorithms. For strategic decision-making, data-driven insights are increasingly essential in sports analytics.

PROPOSED METHODOLOGY

The methodology for unveiling the IPL league winner involves a reiterative process that take part in data collection, preprocessing, model selection, and validation. The fundamental objective is to implement a prophetic model that can accurately conjecture the potential winner of IPL 2024.

Data Collection

An all-inclusive dataset is gathered from Kaggle encompassing historical IPL match data from various seasons. This embraces complete statistics such as venues, toss decisions, team names, winners, and circumstantial factors. This dataset has extracted meaningful features that contribute to match results.



**Data Preprocessing**

The gathered data is imperilled to preprocessing to remove whitespace, handle missing values, and correct team names. Feature engineering plays a decisive role in this stage, label encoding is used to convert the string into a numerical value in the team column.

Model Selection

As from the referred paper, the RFC model gives optimal accuracy compared with other ML algorithms mentioned, and this paper is built using a random forest classifier algorithm predicting IPL league outcomes.

Training And Tuning

The dataset is split into training and testing sets based on the Season column. For the training stage matches up to the 2023 season are considered, while for testing twenty-24 season is undertaken. The chosen model is trained on a training dataset. The projected labels are mapped back to team names using a predefined mapping.

Model Validation

The predictive model is corroborated using a dataset not used during the training stage. Accuracy metrics are hired to appraise the model's performance are plotted.

Findings

The forecasted league winners of IPL 2024 are reported with accuracy scores. This methodology aims to provide a full-bodied and steady machine-learning framework for estimating the winner of a league, causal to the mounting field of sports analytics and enhancing our understanding of the factor that is causative to feat on T-20 cricket.

Visualization: Univariate Analysis

Fig 1 reveals a horizontal bar chart that Mumbai Indians (MI) leads with a score of 133, followed closely by Chennai Super Kings (CSK) at 125 and Kolkata Knight Riders (KKR) at 124, indicating they are the top-performing teams. Royal Challengers Bangalore (RCB), Sunrisers Hyderabad (SRH), Rajasthan Royals (RR), Delhi Capitals (DC), and Pune Warriors (PW) fall into a mid-range performance bracket, with scores ranging from 96 to 108. In contrast, Lucknow Super Giants (LSG) and Gujarat Titans (GT) are significantly behind, with the lowest scores of 44 and 36 respectively, highlighting a notable disparity in performance levels among the teams. Fig 2 represents the top 10 cricket stadiums by the number of matches played. Wankhede Stadium tops the list with (111) matches, followed by Eden Gardens (77) and M Chinnaswamy Stadium (63). Other notable venues include Feroz Shah Kotla (59), MA Chidambaram Stadium (48), and Rajiv Gandhi International Stadium, Uppal (47). Sawai Mansingh Stadium also hosted 47 matches, while Punjab Cricket Association Stadium (34), Sheikh Zayed Stadium (29), and Maharashtra Cricket Association Stadium (22) round out the list. Wankhede Stadium stands out as the most frequently used venue. Fig 3 discloses Out of the total matches conducted from the first season to last season the decision spellbound each team after winning the toss, 616 times chose to field first, and 345 times they chose to bat first. This shows that after the toss decision, most of the team prefers to field first.

Prediction And Accuracy Evaluation

The Foreseen team, based on historical data and relevant features, suggests that has the highest likelihood of winning with a 64.48% accuracy score. However, the accuracy score indicates some uncertainty, and real-world outcomes may differ due to various factors.

CONCLUSION

Envisaging a winner in a field of sport is arduous and involves very convoluted methods, especially in cricket. but with the mystical arts of machine learning is easier. This work has an effect in predicting Kolkata Knight Riders as the champion of the 17th edition of IPL twenty- twenty-four using a Random Forest classifier to be the optimal





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achievement of a 64.24% accuracy score. As future scope to foreshow IPL league, as a hybrid approach incorporates player statistics, team strength, and historical data that could offer a comprehensive prophesied model. However, predicting a winner may not be correct in every situation this might change due to climatic conditions, auction reports, and player injury. consider social media sentiment to gauge fan support or use deep learning techniques to categorize patterns in historical match data.

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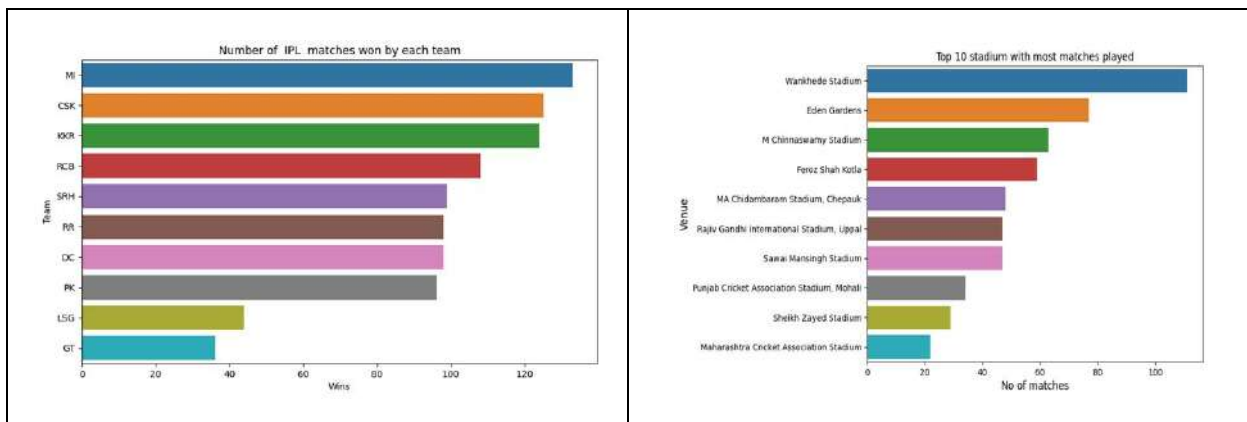


Figure.1: Number of Match Won By Each Team

Figure.2: Top 10 Stadium With Most Matches Played

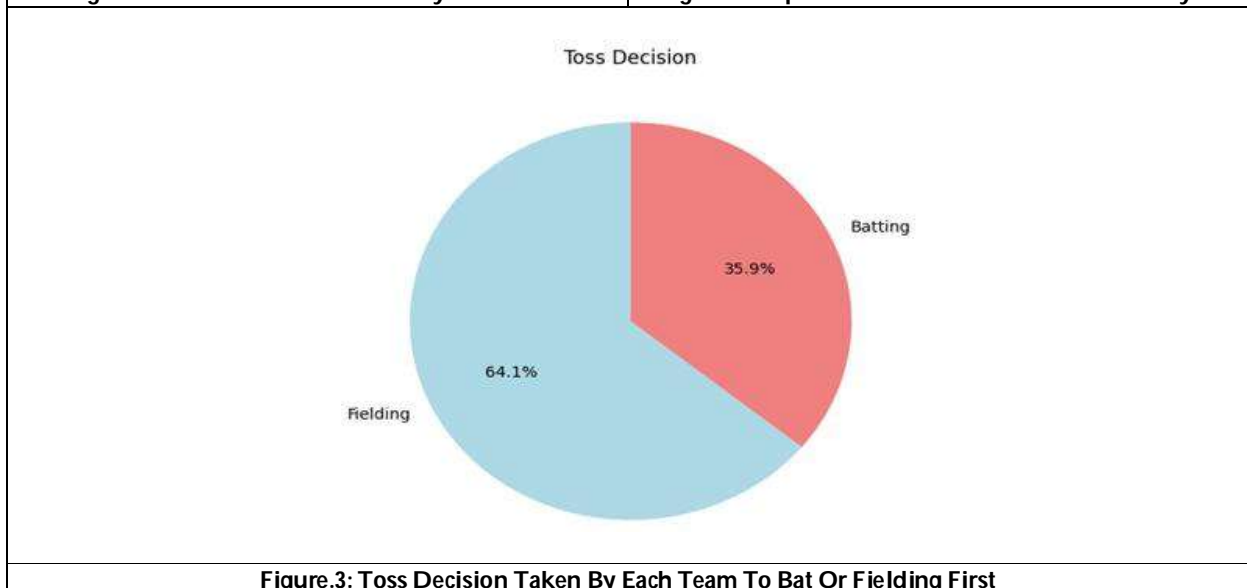


Figure.3: Toss Decision Taken By Each Team To Bat Or Fielding First





Ayurvedic Management of Dusta Vrana w.s.r Pressure Ulcer [Bed Sore]: A Single Case Study

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ABSTRACT

Pressure ulcers, also known as bedsores or decubitus ulcers, are localized injuries to the skin and underlying tissue, typically over bony prominences, resulting from prolonged pressure, shear, and friction. These wounds pose significant clinical challenges, particularly in vulnerable populations such as the elderly, individuals with limited mobility, and those with chronic illnesses. The development of pressure ulcers is associated with various risk factors including immobility, malnutrition, incontinence, and impaired sensory perception. The management of bedsores is crucial to improving patient outcomes and preventing complications. Traditional medicine offers various approaches, including the local application of herbal formulations. Jatayadi Tail, an herbal oil enriched with healing properties, is commonly used for its anti-inflammatory and wound-healing effects. Additionally, Panchavalkal Kwath, provides nourishment to the affected tissues and enhances the healing process. The practice of Prakshalan, or local washing with Panchavalkal Kwath, helps cleanse the wound, reduce infection risk, and promote tissue regeneration. This combination of topical applications demonstrates potential efficacy in managing bedsores, improving healing rates, and enhancing patient comfort.

Keywords: Bed Sore, Pressure ulcer, Dusta vrana, Panchwalkal kwath, Prakshalan, jatyaditail, local application



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INTRODUCTION

An ulcer is a break in the continuity of the covering epithelium, either skin or mucous membrane due to molecular death. [1] the bed sore also known as pressure ulcer and trophic ulcer. Pressure sore is tissue necrosis and ulceration due to prolonged pressure. Blood flow to the skin stops once external pressure becomes more than 30 mmHg (more than capillary occlusive pressure) and this causes tissue hypoxia, necrosis and ulceration. It is more prominent between bony prominences and an external surface. [2] The pressure sores are most common site over the ischial tuberosity, sacrum, the heel, buttocks, more common in long term bedridden patients, elderly, immobile, unconscious or paralyzed patient. Bedsore or Pressure ulcer is defined by the European Pressure Ulcer Advisory Panel (EPUAP) as an area of localised damage to the skin and underlying tissue caused by pressure, shear or friction or a combination of these. [3] In ayurveda mainly 2 types of vrana will be described nija and agantuja vana. nijavran. Is manifested to dosha vata, pitta, kapha sannipataj and Agantuj vana is external injury in sharia that cause to vrana [4] Acharya charak also explain nija and agantujavrana [5] According to acharya sushruta has ulcer will be correlated with nija vana [6] Nowadays, doctors administer treatments like betadine, silver nitrate, H₂O₂, Eusol, antibiotics, or any other medications that are used in daily practice. although Sushrutaacharya has already explain that Sasti Upakramas can treat any kind of vana (wound). [7] Vrana chikitsa mainly based on in 6 mula, 8 adhistan, 5 lakshan, 60 upakarama and chatushpada [8]

Aim and objective

This study was establishing the ayurvedic management of dushta vana [pressure ulcer] and prevention of recurrence.

Case report

A 40-year-old female patient came with a history of spinal injury due to a fall of height in six months ago. She currently presents with paraparesis (weakness affecting both legs), Uncontrolled bladder and bedsores in the lumbosacral region. After the surgery patient was totally bedrest and they have gradually developed bed sore in lumbosacral region with serous discharge and foul smell in 2 months ago, during general physical examination patient was malnourished vital are stable and laboratory investigation within normal range. neurological examination show motor reflex of both limbs were diminished.

Past history

Patient having a history of the spinal injury [C2;C3;C4] due to fall down to first floor of her house since 6 months ago and also surgery will be done.

Ulcer examination [9]

➤ Inspection

Site; lumbosacral region

Size; 8 cm long Approx 5 cm width

Shape; irregular

Number; 1

Discharge; little serous discharge present

Smell; foul smell

Surrounding area; discolorations present

Flora; Debris present

➤ Palpation

Temperature: normal

Tenderness: present

Margins: irregular





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Bleeding: not present

Surrounding area: not edematous

Classification of Pressure Ulcers By Grade, Defined By European Pressure Ulcer Advisory Panel (Epuap):

Grade 1: Non- blanchable erythema of intact skin. Discoloration, warmth, induration or hardness of skin may also be used as indicators, particularly in people with darker skin.

Grade 2: partial thickness skin loss, involving epidermis, dermis or both. The ulcer is superficial and presents clinically as abrasion or blister.

Grade 3: Full thickness skin loss involving damage to or necrosis of subcutaneous tissue that may extend down to, but not through underlying fascia.

Grade 4: Extensive destruction, tissue necrosis, or damage to muscle, bone or supporting structures, with or without full thickness skin loss.

MATERIAL AND METHODS

The proper management of the ulcer to relevant treatment of which including both internal and external application form of shodhan and ropan concept of dusta vrana.

External and internal medicine

External application of panchavalakal kwath for prakshalan [cleaning, washing] purpose and jatyadi tail for local application

➤ Panchavalakal kwath

Panchavalakal kwath Combining the vran shodhak and vran ropak qualities of the sixty upakramas of vrana management mentioned in the Sushrut Samhita, panchavalakal kwath is beneficial. It is thought that Panchavalakal Kwath acts through raktapittagna and kapha shamak. Its kashaya (astringent) rasa, tikta (bitter) rasa, and ruksha (dry) properties have several activities, including removing slough and providing the right environment for injured tissue cells to begin regenerating.[10] These gunas work well to normalize vitiated kapha. that removal of symptoms such as dourgandhya, kandu, and srava. While it's beneficial to promote healing and pain relief. Additionally, kwatha has demonstrated antimicrobial properties in past research studies [11]. Throughout the management, no unfavorable occurrences were discovered, and the healing process went smoothly. The found way of therapy. affordable, secure, and simple to use

➤ Jatyadi tail [13]

Jatyadi Taila is a traditional Ayurvedic formulation used primarily for wound healing and skin conditions. Its scientific application can be understood through its properties and ingredients:

- Ingredients and Their Effects:
 - Tikta (bitter) and Kashaya (astringent) Rasa: These tastes help in reducing inflammation and promoting tissue healing.
 - Laghu (light) and Ruksha (dry) Guna: These qualities contribute to reducing excess moisture in wounds and accelerating healing by facilitating the drying and closure of wounds.
- Properties of Ingredients:
 - Raktaprasadak Dravya (Blood Purifiers): Manjistha and Sariva help in enhancing blood quality (Rakta dhatu), which supports better tissue perfusion and healing. Improved blood circulation can lead to more efficient delivery of nutrients and removal of waste products from the wound site.
 - Katuka: This ingredient supports re-epithelialization (regrowth of the outer skin layer), neovascularization (formation of new blood vessels), and migration of cells (like endothelial cells) into the wound area, thus aiding in the overall healing process.



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- Mechanism:
 - Vrana Ropana (Wound Healing): The combined actions of the ingredients work synergistically to promote wound healing. The bitter and astringent qualities help in reducing inflammation and controlling infection, while the light and dry qualities prevent excessive moisture that can hinder healing.
 - Strengthening Tissues: The formulation supports the stabilization of skin and underlying tissues by enhancing the strength of both the skin (twak) and the muscles (mamsa). This makes the tissue more resilient and less prone to further injury or infection.
 - Improved Blood Circulation: By enhancing the quality of blood and promoting better perfusion, Jatyadi Taila ensures that the wound site receives adequate nutrients and oxygen necessary for repair and regeneration.
 - Application
 - Topical Use: Jatyadi Taila is typically applied topically to wounds or affected areas. It should be applied to clean, dry skin to maximize its healing benefits.
- Jatyadi Taila utilizes its blend of ingredients to support wound healing through anti-inflammatory, astringent, and tissue-strengthening properties, backed by scientific principles of enhancing blood flow and tissue regeneration. At the end of 45 days the dusta vran is complete to healed.

Gandhaka rasayana

Gandhaka rasayana has anti-inflammatory and anti-infective properties, it helps in wound healing.

Arogyavardini vati

Arogyavardini vati helps to expel the vitiated pitta, helps to reduce inflammation, burning sensation.

Amapachakvati: improving digestive health .

Procedure

Patient consent was taken, the ulcer and the surrounding area was cleaned with panchvalkal kashaya regularly. After cleaning of the ulcer, Jatyadi taila sufficient quantity was applied over the ulcer. Then the ulcer was covered with dry gauze bandaging was done

RESULT

According to EDUAP it is Grade 3: Full thickness skin loss involving damage to or necrosis of subcutaneous tissue that may extend down to, but not through understanding fascia. On the 0 day ulcer which was having to much large with mucopurulent discharge with foul intorlable smell with pain which turned into ½ previous ulcer area with healthy granulation and little wet dressing discharge on 15th day after the application of medicine internal and also externally, further wound was improved size will bedecreased with healthy granulation tissue and no discharge and no smell from 30th day to start with epithelization to get completely healed by 45th with the continuation of same treatment.

DISCUSSION

The treatment of bedsores (also known as pressure ulcers) has both modern and traditional approaches. According to Ayurvedic principles, as described by Acharya Sushruta, the management of dusta vrana (chronic wounds, such as bedsores) is based on the involvement of doshas, site of the wound, and the degree of purification and inflammation. The combination of Amapachak Vati, Arogya Vardhini Vati, and Gandhak Rasayan is an Ayurvedic treatment protocol traditionally used for managing and healing bed sore

1.Amapachak Vati: This is primarily aimed at enhancing digestive efficiency and metabolizing endotoxins, referred to as "Ama" in Ayurveda. From a scientific perspective, improving digestive health and systemic detoxification may play a role in improving immune function and accelerating tissue repair in chronic wounds such as bed sores.



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2. Arogya Vardhini Vati: This formulation supports liver function and enhances the body's detoxification pathways. Scientific studies suggest that liver function is critical in regulating inflammation and tissue regeneration. Enhanced liver detoxification, along with the regulation of lipid metabolism, may promote faster healing of skin lesions by improving blood purification and tissue repair processes.

3. Gandhak Rasayan: Sulfur (Gandhak) is known for its broad antimicrobial, anti-inflammatory, and wound-healing properties. Modern research has shown that sulfur-based compounds can promote skin regeneration, reduce microbial load, and enhance wound healing. Gandhak Rasayan's role in reducing infection rates in bed sores and supporting dermal repair makes it a potent adjunct in managing pressure ulcers.[15]

The combination of Panchavalkal prakashalan and the local application of Jatyadi taila proves to be highly effective in managing chronic wounds like bedsores. Panchavalkal prakashalan offers deep cleansing and detoxification, reducing inflammation and infection due to its antimicrobial properties. Meanwhile, Jatyadi taila, with its wound-healing and tissue-regenerating qualities, promotes the formation of healthy granulation tissue. Together, these Ayurvedic treatments facilitate faster healing, reduce discomfort, and improve overall wound management outcomes[16]

CONCLUSION

The study on Ayurvedic management of pressure ulcers (bed sores) is that a combination of internal and external Ayurvedic treatments proved to be highly effective in healing chronic wounds like bedsores. The treatment included Panchavalkal kwath for cleaning the wound and Jatyadi taila for topical application, which promoted tissue regeneration and healing. Additionally, internal medicines such as Amapachak Vati, Arogya Vardhini Vati, and Gandhak Rasayan helped in detoxification, improving immune response, and promoting faster healing. The study demonstrated complete healing of the wound within 45 days without any adverse effects.

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Table.1: Internal Medicine

Gandhak rasayan	2-0-2	A/F
Arogyavardhini vati	2-0-2	A/F
Amapachak vati	2-0-2	A/F

Table.2:Assessment [14]

Parameter for Assessment	Gradations criteria 0	+	++	+++
Size	No discontinuity of skin/mucous membrane	¼ of previous area of the ulcer	½ of previous area of the ulcer	>½ of previous area of the Ulcer
Pain	No pain	Localized pain during movement but relieved on rest	Localized pain even during rest	localized pain even during rest and also towards other side
Discharge	No discharge/ dry dressing	Scanty, occasional discharge/ Little wet dressing	Often discharge needs daily dressing	Profuse, continuous discharge needs frequent dressing
Smell	No smell	Bad smell	Tolerable, unpleasant smell	Foul and intolerable smell
Edge	Adhere edge	Smooth, even and regular edge	Rough, irregular edge	angry look
Floor	Floor Smooth, regular with granulation tissue/ No need for dressing	Rough, regular, mild discharge, less granulation tissue/ needs dressing	Unhealthy, less granulation tissue/ needs daily dressing	Unhealthy, no granulation





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Table.3: Assessment

Sign and symptoms	before treatment 0 day	After 15 days	30 days	45 days
Size	+++	++	+	0
Pain	++	+	+	0
Discharge	++	+	0	0
Smell	+++	++	+	0
Edge	+++	++	+	0
Floor	+++	++	+	0



Figure.1: [ulcer with tissue damage]



Figure.2: [healing with granulation]



Figure.3:[further healing process]



Figure.4:[Near to complete healing]





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Figure.5:[complete healing pressure ulcer]





Arduino based Rescue System with GPS Alerts for Women's Safety using Proteus

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ABSTRACT

This project presents the design and implementation of a women's safety rescue system using Arduino, GPS, and GSM modules, simulated in Proteus. The system enables women to send an immediate distress signal with their location coordinates to a predefined contact in case of an emergency. By pressing a button, the device triggers the GPS module to fetch the current location, and the GSM module sends an SMS alert containing the GPS coordinates. Additionally, the system activates a buzzer to draw attention. The entire setup is designed to be portable and user-friendly, ensuring quick and efficient assistance. The use of Proteus for simulation allows for thorough testing of the circuit before physical implementation.

Keywords: Women safety, Arduino, GPS Module, GSM Module.

INTRODUCTION

The Women's safety remains a critical issue in many parts of the world. Incidents of violence and harassment continue to rise, leading to a growing demand for effective measures that ensure personal security. Technological advancements offer significant potential in addressing these concerns [5]. This project focuses on developing a sophisticated rescue system based on Arduino, integrated with GPS alerts, specifically designed to enhance the safety of women. The core idea behind this system is to provide a quick and reliable method for women to alert their trusted contacts in case of an emergency [3]. By pressing a simple button, the device will send an SMS containing their precise location coordinates to a predefined contact, ensuring immediate assistance. The system integrates

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several key components, including a GPS module for location tracking, a GSM module for sending alerts, and an Arduino board for processing and control [2]. Additional features such as a buzzer and LED are incorporated to draw attention in critical situations. The project also leverages Proteus software for circuit simulation, allowing for comprehensive testing and validation of the system before physical implementation [4]. This ensures that the design is robust, functional, and capable of performing reliably in real-world scenarios. Through this project, we aim to create a portable, cost-effective, and user-friendly device that empowers women to feel safer and more secure in their daily lives [1]. By providing a technological solution to a pressing social issue, this project highlights the importance of innovation in enhancing personal safety and underscores the potential of technology to create a safer world for everyone[7]. The development of this rescue system not only aims to enhance women's safety but also demonstrates the potential of technology in addressing social issues. By providing a practical and accessible solution, this project highlights the importance of innovation in creating a safer and more secure environment for women [6]. The successful implementation of this system can serve as a model for similar projects aimed at improving personal security and empowering individuals to take control of their safety.

Block Diagram Representation

In figure 1 it appears the associations of the framework. Arduino Microcontroller acts as the central control unit. Forms signals from GPS and other inputs (e.g., button press) and communicates with the GSM module. GPS Module tracks the current area of the gadget in terms of scope and longitude and gives area information to the Arduino. GSM Module (SIM900) sends crisis messages (SMS) containing the user's GPS area to predefined contacts. Push Button serves as the emergency trigger. When pressed, it enacts the protect framework. LCD Show shows framework status, such as "Caution Sent," or area facilitates and gives criticism to the client approximately framework operations. Buzzer produces an capable of being heard alarm to draw consideration to the crisis circumstance. The framework will send the GPS area as an SMS, and the sent message will appear within the Virtual Terminal. When the push button is pressed: The LCD appears framework status, counting "Sending Alarm" and "Caution Sent."The Virtual Terminal shows GSM communication: AT Commands and reactions and sent SMS: Emergency! Area: Lat: xx.xxxx, Lon: yy.yyyy.

System Design

The project "Arduino based rescue system with GPS alerts for women" is a arduino based software project. In this project we use proteus software version 8.11 to design the circuit. We use virtual terminal to get the results of this circuit. In table 1 it shows the connections of different component used in the system design.

Operating Principal of The System

The main purpose of our project is to provide security to the women from unsafe situations. When powered on, the Arduino initializes all connected components and configures the GPS module to start acquiring location data and sets up the GSM module to send SMS. It also initializes the LCD to display system messages. The GPS module continuously tracks the current location and the system remains idle and ready for activation. This device consists of a push button which can be pressed by the women when she is in need or when she feels insecure. As the switch is pressed by the women the arduino uno gets the command and it takes the current latitude and longitude value of the victim with the help of GPS module. The arduino uno switch ON the buzzer present in the device so that nearby people may notice the critical condition and may come to rescue. And arduino uno sends the SMS of current location to the registered mobile number of the family member and police with the help of GSM module. The GSM sends the current position at every second so that if the victim is changing its current position continuously then that can be easily followed by police. The system continues monitoring the GPS location and can resend alerts if the button is pressed again. Figure 3 shows the working of the system in form of a flow chart.





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RESULT

Simulating results of “WOMEN SAFETY RESCUE SYSTEM” circuit in Proteus 8.11 is shown and discussed below- Figure 4, shows when powered on, the Arduino initializes all connected components. The LCD displays the message “Initializing..” and when the system is ready it shows “ System Ready”. In figure 5, shows when the push button is pressed the buzzer is activated to produce a loud alarm. An emergency alert message is prepared, including the location coordinates to send via GSM module to predefined emergency contacts. In figure 6, shows the message is sent via the GSM module to predefined emergency contacts.

CONCLUSION

The Arduino-based rescue system with GPS alerts for women's safety is an effective solution that leverages technology to enhance personal security. The system's ability to send real-time location information to a trusted contact can significantly reduce response times during emergencies and potentially save lives. The successful simulation of the system in Proteus demonstrates its feasibility and reliability. Future enhancements could include integrating additional features such as voice recognition and real-time tracking to further improve the system's functionality. This project underscores the importance of technological innovations in addressing social issues and providing practical solutions for women's safety.

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Table.1: Circuit Connection of the System

Component	Pin Name	Connected To	Notes
GSM Module	TX	Arduino D0 (RX)	Communication via Software Serial.
	RX	Arduino D1 (TX)	
	VCC	5V	Requires stable 5V and 2A current.
	GND	GND	Common ground with Arduino.
GPS Module	TX	Arduino D9 (RX)	Communication via Software Serial.
	VCC	5V	
	GND	GND	





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LCD (16x2)	RS	Arduino D12	Used for control signals.
	E	Arduino D11	
	D4, D5, D6, D7	Arduino D5, D4, D3, D2	Data pins in 4-bit mode.
	VCC	5V	
	GND	GND	
	Contrast (V0)	GND	
Buzzer	Positive (+)	Arduino D6	Generates audible alarm.
	Negative (-)	GND	
Push Button	One Terminal	Arduino D10	Trigger for SOS alert.
	Other Terminal	GND	
Power Supply	5V	Arduino Power Jack	Ensure common ground.

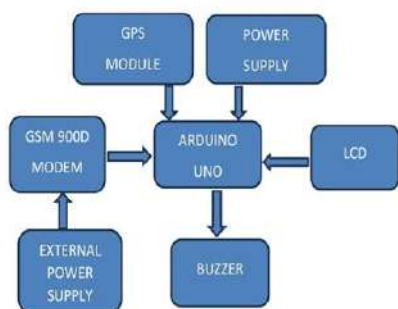


Figure.1:Block Diagram of Women Safety Rescue System

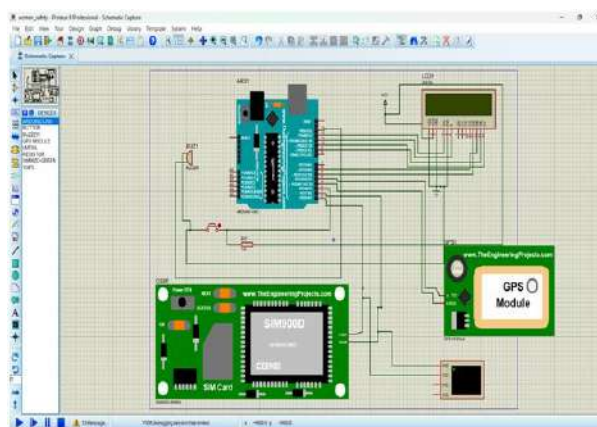


Figure.2: Circuit Design Using Proteus 8.11

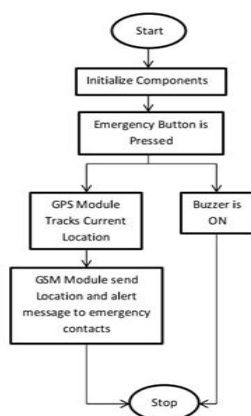


Figure.3: Flow chart of the System

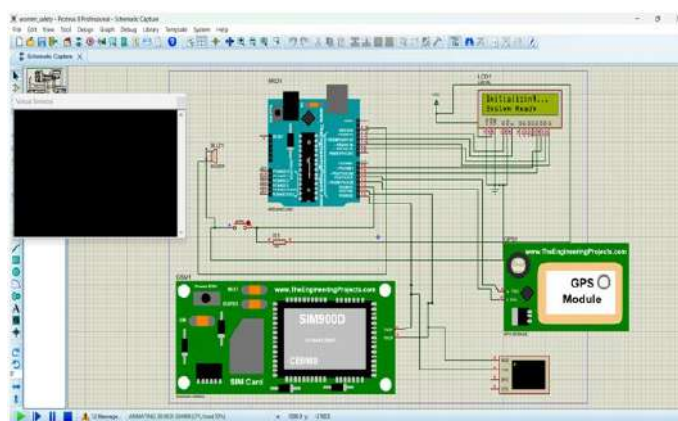


Figure.4: Working Circuit of Women Rescue System where Initialization of components occurs



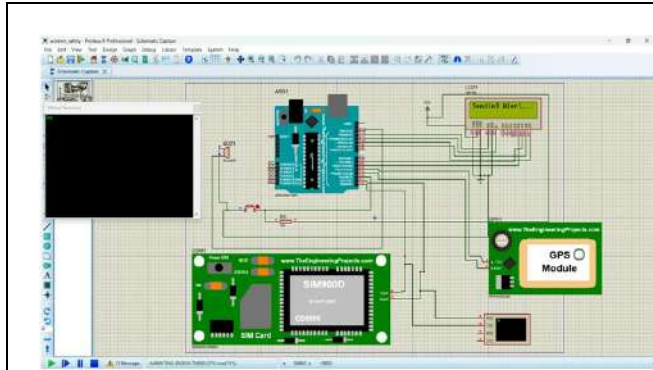


Figure.5: Circuit when the push button is pressed

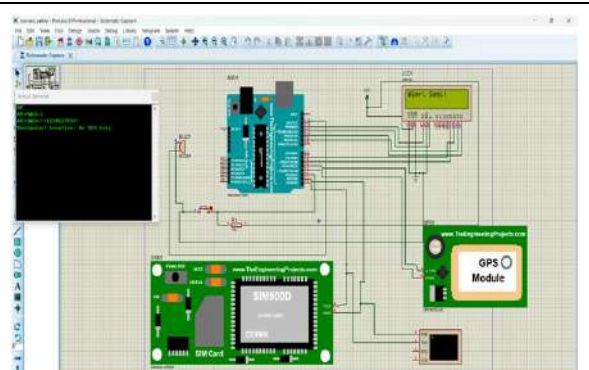


Figure.6: Circuit when SMS send via GSM





Interval Valued Bipolar Intuitionistic Fuzzy Ideal and Fuzzy α -Ideal of a BP-Algebra

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ABSTRACT

A distinct algebraic structure of BP-algebra is provided by an interval valued bipolar intuitionistic fuzzy ideal and fuzzy α -ideal. Here, the properties are explained with new concepts. The goal of this research is to apply fuzzy set and ideal theory to a BP-algebra.

Keywords: BP-algebra, bipolar intuitionistic fuzzy ideal, interval valued bipolar intuitionistic fuzzy ideal and fuzzy α -ideal.

INTRODUCTION

In early period L.A.Zadeh [9] introduced a fuzzy set of his own but now its area was developed into so many categories in this modern age. The idea behind BP-algebra was introduced by S.S. Ahn[1]. Bipolar valued fuzzy sets were first developed by K.J. Lee [5], who extended $[-1, 1]$ from $[0, 1]$ with a positive membership degree range of fuzzy sets. The elements that are unrelated to the associated property are indicated by the membership degree of 0. In addition to partially satisfying the implicit counter property, which displays the negative membership degree $[-1, 0]$,





the elements also partially satisfy the property means the positive membership degree (0, 1]. W.R. Zhang [10] began the generalization of fuzzy sets in 1994. A union and intersection of intuitionistic fuzzy sets were described by K. Chakrabarty and Biswas R. Nanda [4]. Fuzzy groups and level subgroups were scrutinized by A. Rajeshkumar [8]. The authors M. Palanivelrajan and S. Nandakumar [7] defined intuitionistic fuzzy primary and semi primary ideal operations. The bipolar fuzzy α -ideal of the BP algebra was defined by Gendy [6]. S. Sivakaminathan, K. Gunasekaran, and S. Nandakumar [11] proposed further operations on the bipolar intuitionistic fuzzy ideal and anti fuzzy ideal of a BP-algebra. As an extension of the traditional fuzzy set, intuitionistic fuzzy sets were first presented by K.T. Atanassov [2]. As a basis for intuitionistic fuzzy sets, interval valued intuitionistic fuzzy sets were further proposed by K.T. Atanassov and G. Gargov [3].

MATERIALS AND METHODS

Definition:2.1

For BP-algebra X , a BIF set A is defined as $A = \{(x, \mu_A^P(x), \mu_A^N(x), \nu_A^P(x), \nu_A^N(x)) \mid x \in X\}$, where $\mu_A^P: X \rightarrow [0, 1]$, $\mu_A^N: X \rightarrow [-1, 0]$, $\nu_A^P: X \rightarrow [0, 1]$, $\nu_A^N: X \rightarrow [-1, 0]$ are mappings and it satisfies $0 \leq \mu_A^P(x) + \nu_A^P(x) \leq 1$ and $-1 \leq \mu_A^N(x) + \nu_A^N(x) \leq 0$.

Definition:2.2

In X , A and B are any two BIF sets $A = (\mu_A^P, \mu_A^N, \nu_A^P, \nu_A^N)$ and $B = (\mu_B^P, \mu_B^N, \nu_B^P, \nu_B^N)$, we describe

- (i) $A \cap B = \{(x, \min(\mu_A^P(x), \mu_B^P(x)), \max(\mu_A^N(x), \mu_B^N(x)), \max(\nu_A^P(x), \nu_B^P(x)), \min(\nu_A^N(x), \nu_B^N(x))) \mid x \in X\}$
- (ii) $A \cup B = \{(x, \max(\mu_A^P(x), \mu_B^P(x)), \min(\mu_A^N(x), \mu_B^N(x)), \min(\nu_A^P(x), \nu_B^P(x)), \max(\nu_A^N(x), \nu_B^N(x))) \mid x \in X\}$
- (iii) $\bar{A} = \{(x, \nu_A^P(x), \nu_A^N(x), \mu_A^P(x), \mu_A^N(x)) \mid x \in X\}$.

Definition: 2.3

A function $M_A: X \rightarrow D[0, 1]$, $\forall x \in X$, $M_A(x)$ is an interval $[a, b]$, $0 \leq a \leq b \leq 1$ and IVF set A is brought out by the expression $D[0, 1]$, which represents the set of all intervals inside $[0, 1]$.

Definition:2.4

The set $A = \{(x, m_A^P(x), m_A^N(x), n_A^P(x), n_A^N(x)) \mid x \in X\}$, where $m_A^P(x) \subseteq [0, 1]$, $m_A^N(x) \subseteq [-1, 0]$, $n_A^P(x) \subseteq [0, 1]$ and $n_A^N(x) \subseteq [-1, 0]$ are interval and $\forall x \in X$, $\inf m_A^P(x) + \inf n_A^P(x) \leq 1$, $\sup m_A^N(x) + \sup n_A^N(x) \geq -1$, we can able to obtain the IVBIF set A over X .

Example:

Consider $\mu_A^P(x) = \inf m_A^P(x) = \begin{cases} [0.7, 0.7] & \text{if } x = 0 \\ [0.3, 0.7] & \text{otherwise} \end{cases}$
 $\mu_A^N(x) = \sup m_A^N(x) = \begin{cases} [-0.8, -0.8] & \text{if } x = 0 \\ [-0.8, -0.6] & \text{otherwise} \end{cases}$
 $\nu_A^P(x) = \inf n_A^P(x) = \begin{cases} [0.2, 0.2] & \text{if } x = 0 \\ [0.2, 0.5] & \text{otherwise} \end{cases}$
 $\nu_A^N(x) = \sup n_A^N(x) = \begin{cases} [-0.1, -0.1] & \text{if } x = 0 \\ [-0.3, -0.1] & \text{otherwise} \end{cases}$

Definition:2.5

In X , A and B are any two IVBIF sets $A = (\mu_A^P, \mu_A^N, \nu_A^P, \nu_A^N)$ and $B = (\mu_B^P, \mu_B^N, \nu_B^P, \nu_B^N)$, we define

- (i) $A \cap B = \{(x, \min(\inf m_A^P(x), \inf m_B^P(x)), \max(\sup m_A^N(x), \sup m_B^N(x)), \max(\inf n_A^P(x), \inf n_B^P(x)), \min(\sup n_A^N(x), \sup n_B^N(x))) \mid x \in X\}$
- (ii) $A \cup B = \{(x, \max(\inf m_A^P(x), \inf m_B^P(x)), \min(\sup m_A^N(x), \sup m_B^N(x)), \min(\inf n_A^P(x), \inf n_B^P(x)), \max(\sup n_A^N(x), \sup n_B^N(x))) \mid x \in X\}$





$$(iii) \bar{A} = \{(x, \inf n_A^P(x), \sup n_A^N(x), \inf m_A^P(x), \sup m_A^N(x)) / x \in X\}.$$

Definition:2.6

An IVBIF set A of BP-algebra X is named as an IVBIF ideal of X if it attains the following constraints:

- (i) $\inf m_A^P(0) \geq \inf m_A^P(x)$ and $\sup m_A^N(0) \leq \sup m_A^N(x)$
- (ii) $\inf m_A^P(x) \geq \min \{ \inf m_A^P(x \cdot y), \inf m_A^P(y) \}$
- (iii) $\sup m_A^N(x) \leq \max \{ \sup m_A^N(x \cdot y), \sup m_A^N(y) \}$
- (iv) $\inf n_A^P(0) \leq \inf n_A^P(x)$ and $\sup n_A^N(0) \geq \sup n_A^N(x)$
- (v) $\inf n_A^P(x) \leq \max \{ \inf n_A^P(x \cdot y), \inf n_A^P(y) \}$
- (vi) $\sup n_A^N(x) \geq \min \{ \sup n_A^N(x \cdot y), \sup n_A^N(y) \}, \forall x, y \in X.$

Illustration

An IVBIF set $A = \{ \mu_A^P, \mu_A^N, \nu_A^P, \nu_A^N \}$, whereas

$$\begin{aligned} \mu_A^P(x) = \inf m_A^P(x) &= \begin{cases} [0.7, 0.7] & \text{if } x = 0 \\ [0.3, 0.7] & \text{otherwise} \end{cases} \\ \mu_A^N(x) = \sup m_A^N(x) &= \begin{cases} [-0.8, -0.8] & \text{if } x = 0 \\ [-0.8, -0.6] & \text{otherwise} \end{cases} \\ \nu_A^P(x) = \inf n_A^P(x) &= \begin{cases} [0.2, 0.2] & \text{if } x = 0 \\ [0.2, 0.5] & \text{otherwise} \end{cases} \\ \nu_A^N(x) = \sup n_A^N(x) &= \begin{cases} [-0.1, -0.1] & \text{if } x = 0 \\ [-0.3, -0.1] & \text{otherwise} \end{cases} \end{aligned}$$

Hence, the above mentioned six conditions are checked and carried out by set A.

Definition:2.7

In this IVBIF set $A = \{ (x, \mu_{\alpha_A}^P(x), \mu_{\alpha_A}^N(x), \nu_{\alpha_A}^P(x), \nu_{\alpha_A}^N(x)) / x \in X \}$ of X is entitled as an IVBIF α -ideal of X if it fulfills the below statements:

- (i) $\inf m_{\alpha_A}^P(0) \geq \inf m_{\alpha_A}^P(x)$ and $\sup m_{\alpha_A}^N(0) \leq \sup m_{\alpha_A}^N(x)$
- (ii) $\inf m_{\alpha_A}^P(y \cdot z) \geq \min \{ \inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_A}^P(x \cdot y) \}$
- (iii) $\sup m_{\alpha_A}^N(y \cdot z) \leq \max \{ \sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_A}^N(x \cdot y) \}$
- (iv) $\inf n_{\alpha_A}^P(0) \leq \inf n_{\alpha_A}^P(x)$ and $\sup n_{\alpha_A}^N(0) \geq \sup n_{\alpha_A}^N(x)$
- (v) $\inf n_{\alpha_A}^P(y \cdot z) \leq \max \{ \inf n_{\alpha_A}^P(x \cdot z), \inf n_{\alpha_A}^P(x \cdot y) \}$
- (vi) $\sup n_{\alpha_A}^N(y \cdot z) \geq \min \{ \sup n_{\alpha_A}^N(x \cdot z), \sup n_{\alpha_A}^N(x \cdot y) \}, \forall x, y, z \in X.$

RESULTS AND DISCUSSION**Proposition: 3.1**

If A is an IVBIF ideal of a BP-algebra, then the complement of the complement of a set A is the set A itself.

Proof:

We assume that $0, x, y \in X.$

$$(i) \text{ Now } \inf m_A^P(0) = \inf n_A^P(0)$$

$$= \inf m_A^P(0) \geq \inf m_A^P(x)$$

$$\text{Therefore } \inf m_A^P(0) \geq \inf m_A^P(x)$$

$$\text{Now } \sup m_A^N(0) = \sup n_A^N(0)$$

$$= \sup m_A^N(0) \leq \sup m_A^N(x)$$

$$\text{Therefore } \sup m_A^N(0) \leq \sup m_A^N(x)$$

$$(ii) \text{ Now } \inf m_A^P(x) = \inf n_A^P(x)$$

$$= \inf m_A^P(x)$$





$$\geq \text{Min} \{ \inf m_A^P(x \cdot y), \inf m_A^P(y) \}$$

$$\text{Therefore } \inf m_A^P(x) \geq \text{Min} \{ \inf m_A^P(x \cdot y), \inf m_A^P(y) \}$$

$$\begin{aligned} \text{(iii) Now } \sup m_A^N(x) &= \sup n_A^N(x) \\ &= \sup m_A^N(x) \end{aligned}$$

$$\leq \text{Max} \{ \sup m_A^N(x \cdot y), \sup m_A^N(y) \}$$

$$\text{Therefore } \sup m_A^N(x) \leq \text{Max} \{ \sup m_A^N(x \cdot y), \sup m_A^N(y) \}$$

$$\text{(iv) Now } \inf n_A^P(0) = \inf m_A^P(0)$$

$$= \inf n_A^P(0) \leq \inf n_A^P(x)$$

$$\text{Therefore } \inf n_A^P(0) \leq \inf n_A^P(x)$$

$$\text{Now } \sup n_A^N(0) = \sup m_A^N(0)$$

$$= \sup n_A^N(0) \geq \sup n_A^N(x)$$

$$\text{Therefore } \sup n_A^N(0) \geq \sup n_A^N(x)$$

$$\text{(v) Now } \inf n_A^P(x) = \inf m_A^P(x)$$

$$= \inf n_A^P(x)$$

$$\leq \text{Max} \{ \inf n_A^P(x \cdot y), \inf n_A^P(y) \}$$

$$\text{Therefore } \inf n_A^P(x) \leq \text{Max} \{ \inf n_A^P(x \cdot y), \inf n_A^P(y) \}$$

$$\text{(vi) Now } \sup n_A^N(x) = \sup m_A^N(x) = \sup n_A^N(x)$$

$$\geq \text{Min} \{ \sup n_A^N(x \cdot y), \sup n_A^N(y) \}$$

$$\text{Therefore } \sup n_A^N(x) \geq \text{Min} \{ \sup n_A^N(x \cdot y), \sup n_A^N(y) \}.$$

Proposition:3.2

The intersection of any two sets are VBIF ideal of a BP-algebra.

Proof:

Let us assume that

$$0, x, y \in A \cap B \Rightarrow 0, x, y \in A \text{ and } 0, x, y \in B.$$

$$\text{(i) Now } \inf m_{A \cap B}^P(0) = \text{Min} \{ \inf m_A^P(0), \inf m_B^P(0) \}$$

$$\geq \text{Min} \{ \inf m_A^P(x), \inf m_B^P(x) \}$$

$$= \inf m_{A \cap B}^P(x)$$

$$\text{Therefore } \inf m_{A \cap B}^P(0) \geq \inf m_{A \cap B}^P(x).$$

$$\text{Now } \sup m_{A \cap B}^N(0) = \text{Max} \{ \sup m_A^N(0), \sup m_B^N(0) \}$$

$$\leq \text{Max} \{ \sup m_A^N(x), \sup m_B^N(x) \}$$

$$= \sup m_{A \cap B}^N(x)$$

$$\text{Therefore } \sup m_{A \cap B}^N(0) \leq \sup m_{A \cap B}^N(x).$$

$$\text{(ii) Now } \inf m_{A \cap B}^P(x) = \text{Min} \{ \inf m_A^P(x), \inf m_B^P(x) \}$$

$$\geq \text{Min} \{ \text{Min} \{ \inf m_A^P(x \cdot y), \inf m_A^P(y) \}, \text{Min} \{ \inf m_B^P(x \cdot y), \inf m_B^P(y) \} \}$$

$$= \text{Min} \{ \text{Min} \{ \inf m_A^P(x \cdot y), \inf m_B^P(x \cdot y) \}, \text{Min} \{ \inf m_A^P(y), \inf m_B^P(y) \} \}$$

$$= \text{Min} \{ \inf m_{A \cap B}^P(x \cdot y), \inf m_{A \cap B}^P(y) \}$$

$$\text{Therefore } \inf m_{A \cap B}^P(x) \geq \text{Min} \{ \inf m_{A \cap B}^P(x \cdot y), \inf m_{A \cap B}^P(y) \}.$$

$$\text{(iii) Now } \sup m_{A \cap B}^N(x) = \text{Max} \{ \sup m_A^N(x), \sup m_B^N(x) \}$$

$$\leq \text{Max} \{ \text{Max} \{ \sup m_A^N(x \cdot y), \sup m_A^N(y) \}, \text{Max} \{ \sup m_B^N(x \cdot y), \sup m_B^N(y) \} \}$$





$$= \text{Max}\{\text{Max}\{\sup m_A^N(\mathbf{x} \cdot \mathbf{y}), \sup m_B^N(\mathbf{x} \cdot \mathbf{y})\}, \text{Max}\{\sup m_A^N(\mathbf{y}), \sup m_B^N(\mathbf{y})\}\} = \text{Max}\{\sup m_{A \cap B}^N(\mathbf{x} \cdot \mathbf{y}), \sup m_{A \cap B}^N(\mathbf{y})\}$$

Therefore $\sup m_{A \cap B}^N(\mathbf{x}) \leq \text{Max}\{\sup m_{A \cap B}^N(\mathbf{x} \cdot \mathbf{y}), \sup m_{A \cap B}^N(\mathbf{y})\}$.

$$(iv) \text{ Now } \inf n_{A \cap B}^P(0) = \text{Max}\{\inf n_A^P(0), \inf n_B^P(0)\}$$

$$\leq \text{Max}\{\inf n_A^P(\mathbf{x}), \inf n_B^P(\mathbf{x})\} \\ = \inf n_{A \cap B}^P(\mathbf{x})$$

Therefore $\inf n_{A \cap B}^P(0) \leq \inf n_{A \cap B}^P(\mathbf{x})$.

$$\text{Now } \sup n_{A \cap B}^N(0) = \text{Min}\{\sup n_A^N(0), \sup n_B^N(0)\}$$

$$\geq \text{Min}\{\sup n_A^N(\mathbf{x}), \sup n_B^N(\mathbf{x})\} \\ = \sup n_{A \cap B}^N(\mathbf{x})$$

Therefore $\sup n_{A \cap B}^N(0) \geq \sup n_{A \cap B}^N(\mathbf{x})$.

$$(v) \text{ Now } \inf n_{A \cap B}^P(\mathbf{x}) = \text{Max}\{\inf n_A^P(\mathbf{x}), \inf n_B^P(\mathbf{x})\}$$

$$\leq \text{Max}\{\text{Max}\{\inf n_A^P(\mathbf{x} \cdot \mathbf{y}), \inf n_A^P(\mathbf{y})\}, \text{Max}\{\inf n_B^P(\mathbf{x} \cdot \mathbf{y}), \inf n_B^P(\mathbf{y})\}\}$$

$$= \text{Max}\{\text{Max}\{\inf n_A^P(\mathbf{x} \cdot \mathbf{y}), \inf n_B^P(\mathbf{x} \cdot \mathbf{y})\}, \text{Max}\{\inf n_A^P(\mathbf{y}), \inf n_B^P(\mathbf{y})\}\}$$

$$= \text{Max}\{\inf n_{A \cap B}^P(\mathbf{x} \cdot \mathbf{y}), \inf n_{A \cap B}^P(\mathbf{y})\}$$

Therefore $\inf n_{A \cap B}^P(\mathbf{x}) \leq \text{Max}\{\inf n_{A \cap B}^P(\mathbf{x} \cdot \mathbf{y}), \inf n_{A \cap B}^P(\mathbf{y})\}$.

$$(vi) \text{ Now } \sup n_{A \cap B}^N(\mathbf{x}) = \text{Min}\{\sup n_A^N(\mathbf{x}), \sup n_B^N(\mathbf{x})\}$$

$$\geq \text{Min}\{\text{Min}\{\sup n_A^N(\mathbf{x} \cdot \mathbf{y}), \sup n_A^N(\mathbf{y})\}, \text{Min}\{\sup n_B^N(\mathbf{x} \cdot \mathbf{y}), \sup n_B^N(\mathbf{y})\}\}$$

$$= \text{Min}\{\text{Min}\{\sup n_A^N(\mathbf{x} \cdot \mathbf{y}), \sup n_B^N(\mathbf{x} \cdot \mathbf{y})\}, \text{Min}\{\sup n_A^N(\mathbf{y}), \sup n_B^N(\mathbf{y})\}\}$$

$$= \text{Min}\{\sup n_{A \cap B}^N(\mathbf{x} \cdot \mathbf{y}), \sup n_{A \cap B}^N(\mathbf{y})\}$$

Therefore $\sup n_{A \cap B}^N(\mathbf{x}) \geq \text{Min}\{\sup n_{A \cap B}^N(\mathbf{x} \cdot \mathbf{y}), \sup n_{A \cap B}^N(\mathbf{y})\}$.

Proposition:3.3

The union of any two sets are lVBIF ideal of a BP-algebra, if they are equal.

Proof:

If $A = B \Rightarrow A \cup B = A$ or $A \cup B = B$.

We assume that $0, \mathbf{x}, \mathbf{y} \in A \cup B \Rightarrow 0, \mathbf{x}, \mathbf{y} \in A$ or $0, \mathbf{x}, \mathbf{y} \in B$.

$$(i) \text{ Now } \inf m_{A \cup B}^P(0) = \text{Max}\{\inf m_A^P(0), \inf m_B^P(0)\}$$

$$\geq \text{Max}\{\inf m_A^P(\mathbf{x}), \inf m_B^P(\mathbf{x})\}$$

$$= \inf m_{A \cup B}^P(\mathbf{x})$$

Therefore $\inf m_{A \cup B}^P(0) \geq \inf m_{A \cup B}^P(\mathbf{x})$.

$$\text{Now } \sup m_{A \cup B}^N(0) = \text{Min}\{\sup m_A^N(0), \sup m_B^N(0)\}$$

$$\leq \text{Min}\{\sup m_A^N(\mathbf{x}), \sup m_B^N(\mathbf{x})\}$$

$$= \sup m_{A \cup B}^N(\mathbf{x})$$

Therefore $\sup m_{A \cup B}^N(0) \leq \sup m_{A \cup B}^N(\mathbf{x})$.

$$(ii) \text{ Now } \inf m_{A \cup B}^P(\mathbf{x}) = \text{Max}\{\inf m_A^P(\mathbf{x}), \inf m_B^P(\mathbf{x})\}$$

$$\geq \text{Max}\{\text{Min}\{\inf m_A^P(\mathbf{x} \cdot \mathbf{y}), \inf m_A^P(\mathbf{y})\}, \text{Min}\{\inf m_B^P(\mathbf{x} \cdot \mathbf{y}), \inf m_B^P(\mathbf{y})\}\}$$

$$= \text{Min}\{\text{Max}\{\inf m_A^P(\mathbf{x} \cdot \mathbf{y}), \inf m_B^P(\mathbf{x} \cdot \mathbf{y})\}, \text{Max}\{\inf m_A^P(\mathbf{y}), \inf m_B^P(\mathbf{y})\}\}$$

$$= \text{Min}\{\inf m_{A \cup B}^P(\mathbf{x} \cdot \mathbf{y}), \inf m_{A \cup B}^P(\mathbf{y})\}$$

Therefore $\inf m_{A \cup B}^P(\mathbf{x}) \geq \text{Min}\{\inf m_{A \cup B}^P(\mathbf{x} \cdot \mathbf{y}), \inf m_{A \cup B}^P(\mathbf{y})\}$.

$$(iii) \text{ Now } \sup m_{A \cup B}^N(\mathbf{x}) = \text{Min}\{\sup m_A^N(\mathbf{x}), \sup m_B^N(\mathbf{x})\}$$

$$\leq \text{Min}\{\text{Max}\{\sup m_A^N(\mathbf{x} \cdot \mathbf{y}), \sup m_A^N(\mathbf{y})\}, \text{Max}\{\sup m_B^N(\mathbf{x} \cdot \mathbf{y}), \sup m_B^N(\mathbf{y})\}\}$$

$$= \text{Max}\{\text{Min}\{\sup m_A^N(\mathbf{x} \cdot \mathbf{y}), \sup m_B^N(\mathbf{x} \cdot \mathbf{y})\}, \text{Min}\{\sup m_A^N(\mathbf{y}), \sup m_B^N(\mathbf{y})\}\}$$





$$= \text{Max}\{\sup m_{A \cup B}^N(x \cdot y), \sup m_{A \cup B}^N(y)\}$$

$$\text{Therefore } \sup m_{A \cup B}^N(x) \leq \text{Max}\{\sup m_{A \cup B}^N(x \cdot y), \sup m_{A \cup B}^N(y)\}.$$

$$(iv) \text{ Now } \inf n_{A \cup B}^P(0) = \text{Min}\{\inf n_A^P(0), \inf n_B^P(0)\}$$

$$\leq \text{Min}\{\inf n_A^P(x), \inf n_B^P(x)\}$$

$$= \inf n_{A \cup B}^P(x)$$

$$\text{Therefore } \inf n_{A \cup B}^P(0) \leq \inf n_{A \cup B}^P(x).$$

$$\text{Now } \sup n_{A \cup B}^N(0) = \text{Max}\{\sup n_A^N(0), \sup n_B^N(0)\}$$

$$\geq \text{Max}\{\sup n_A^N(x), \sup n_B^N(x)\}$$

$$= \sup n_{A \cup B}^N(x)$$

$$\text{Therefore } \sup n_{A \cup B}^N(0) \geq \sup n_{A \cup B}^N(x).$$

$$(v) \text{ Now } \inf n_{A \cup B}^P(x) = \text{Min}\{\inf n_A^P(x), \inf n_B^P(x)\}$$

$$\leq \text{Min}\{\text{Max}\{\inf n_A^P(x \cdot y), \inf n_A^P(y)\}, \text{Max}\{\inf n_B^P(x \cdot y), \inf n_B^P(y)\}\}$$

$$= \text{Max}\{\text{Min}\{\inf n_A^P(x \cdot y), \inf n_B^P(x \cdot y)\}, \text{Min}\{\inf n_A^P(y), \inf n_B^P(y)\}\}$$

$$= \text{Max}\{\inf n_{A \cup B}^P(x \cdot y), \inf n_{A \cup B}^P(y)\}$$

$$\text{Therefore } \inf n_{A \cup B}^P(x) \leq \text{Max}\{\inf n_{A \cup B}^P(x \cdot y), \inf n_{A \cup B}^P(y)\}.$$

$$(vi) \text{ Now } \sup n_{A \cup B}^N(x) = \text{Max}\{\sup n_A^N(x), \sup n_B^N(x)\}$$

$$\geq \text{Max}\{\text{Min}\{\sup n_A^N(x \cdot y), \sup n_A^N(y)\}, \text{Min}\{\sup n_B^N(x \cdot y), \sup n_B^N(y)\}\}$$

$$= \text{Min}\{\text{Max}\{\sup n_A^N(x \cdot y), \sup n_B^N(x \cdot y)\}, \text{Max}\{\sup n_A^N(y), \sup n_B^N(y)\}\}$$

$$= \text{Min}\{\sup n_{A \cup B}^N(x \cdot y), \sup n_{A \cup B}^N(y)\}$$

$$\text{Therefore } \sup n_{A \cup B}^N(x) \geq \text{Min}\{\sup n_{A \cup B}^N(x \cdot y), \sup n_{A \cup B}^N(y)\}.$$

Proposition:3.4

If A is an IVBIF α -ideal of a BP-algebra, then the complement of the complement of a set A is the set A itself.

Proof:

We assume that $0, x, y, z \in X$.

$$(i) \text{ Now } \inf m_{\alpha_A}^P(0) = \inf n_{\alpha_A}^P(0)$$

$$= \inf m_{\alpha_A}^P(0) \geq \inf m_{\alpha_A}^P(x)$$

$$\text{Therefore } \inf m_{\alpha_A}^P(0) \geq \inf m_{\alpha_A}^P(x).$$

$$\text{Now } \sup m_{\alpha_A}^N(0) = \sup n_{\alpha_A}^N(0)$$

$$= \sup m_{\alpha_A}^N(0) \leq \sup m_{\alpha_A}^N(x)$$

$$\text{Therefore } \sup m_{\alpha_A}^N(0) \leq \sup m_{\alpha_A}^N(x).$$

$$(ii) \text{ Now } \inf m_{\alpha_A}^P(y \cdot z) = \inf n_{\alpha_A}^P(y \cdot z)$$

$$= \inf m_{\alpha_A}^P(y \cdot z) \geq \text{Min}\{\inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_A}^P(x \cdot y)\}$$

$$\text{Therefore } \inf m_{\alpha_A}^P(y \cdot z) \geq \text{Min}\{\inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_A}^P(x \cdot y)\}.$$

$$(iii) \text{ Now } \sup m_{\alpha_A}^N(y \cdot z) = \sup n_{\alpha_A}^N(y \cdot z)$$

$$= \sup m_{\alpha_A}^N(y \cdot z) \leq \text{Max}\{\sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_A}^N(x \cdot y)\}$$

$$\text{Therefore } \sup m_{\alpha_A}^N(y \cdot z) \leq \text{Max}\{\sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_A}^N(x \cdot y)\}.$$

$$(iv) \text{ Now } \inf n_{\alpha_A}^P(0) = \inf m_{\alpha_A}^P(0)$$

$$= \inf n_{\alpha_A}^P(0) \leq \inf n_{\alpha_A}^P(x)$$





Therefore $\inf n_{\alpha_A}^P(0) \leq \inf n_{\alpha_A}^P(x)$.

Now $\sup n_{\alpha_A}^N(0) = \sup m_{\alpha_A}^N(0)$

$$= \sup n_{\alpha_A}^N(0) \geq \sup n_{\alpha_A}^N(x)$$

Therefore $\sup n_{\alpha_A}^N(0) \geq \sup n_{\alpha_A}^N(x)$.

(v) Now $\inf n_{\alpha_A}^P(y \cdot z) = \inf m_{\alpha_A}^P(y \cdot z)$

$$= \inf n_{\alpha_A}^P(y \cdot z)$$

$$\leq \text{Max} \{ \inf n_{\alpha_A}^P(x \cdot z), \inf n_{\alpha_A}^P(x \cdot y) \}$$

Therefore $\inf n_{\alpha_A}^P(y \cdot z) \leq \text{Max} \{ \inf n_{\alpha_A}^P(x \cdot z), \inf n_{\alpha_A}^P(x \cdot y) \}$.

(vi) Now $\sup n_{\alpha_A}^N(y \cdot z) = \sup m_{\alpha_A}^N(y \cdot z)$

$$= \sup n_{\alpha_A}^N(y \cdot z) \geq \text{Min} \{ \sup n_{\alpha_A}^N(x \cdot z), \sup n_{\alpha_A}^N(x \cdot y) \}$$

Therefore $\sup n_{\alpha_A}^N(y \cdot z) \geq \text{Min} \{ \sup n_{\alpha_A}^N(x \cdot z), \sup n_{\alpha_A}^N(x \cdot y) \}$.

Proposition:3.5

The intersection of any two sets are IVBIF α -ideal of a BP-algebra.

Proof:

Let us assume that

$$0, x, y \in A \cap B \Rightarrow 0, x, y \in A \text{ and } 0, x, y \in B.$$

(i) Now $\inf m_{\alpha_{A \cap B}}^P(0) = \text{Min} \{ \inf m_{\alpha_A}^P(0), \inf m_{\alpha_B}^P(0) \}$

$$\geq \text{Min} \{ \inf m_{\alpha_A}^P(x), \inf m_{\alpha_B}^P(x) \}$$

$$= \inf m_{\alpha_{A \cap B}}^P(x)$$

Therefore $\inf m_{\alpha_{A \cap B}}^P(0) \geq \inf m_{\alpha_{A \cap B}}^P(x)$.

Now $\sup m_{\alpha_{A \cap B}}^N(0) = \text{Max} \{ \sup m_{\alpha_A}^N(0), \sup m_{\alpha_B}^N(0) \}$

$$\leq \text{Max} \{ \sup m_{\alpha_A}^N(x), \sup m_{\alpha_B}^N(x) \}$$

$$= \sup m_{\alpha_{A \cap B}}^N(x)$$

Therefore $\sup m_{\alpha_{A \cap B}}^N(0) \leq \sup m_{\alpha_{A \cap B}}^N(x)$.

(ii) Now $\inf m_{\alpha_{A \cap B}}^P(y \cdot z) = \text{Min} \{ \inf m_{\alpha_A}^P(y \cdot z), \inf m_{\alpha_B}^P(y \cdot z) \}$

$$\geq \text{Min} \{ \text{Min} \{ \inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_A}^P(x \cdot y) \},$$

$$\text{Min} \{ \inf m_{\alpha_B}^P(x \cdot z), \inf m_{\alpha_B}^P(x \cdot y) \} \}$$

$$= \text{Min} \{ \text{Min} \{ \inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_B}^P(x \cdot z) \},$$

$$\text{Min} \{ \inf m_{\alpha_A}^P(x \cdot y), \inf m_{\alpha_B}^P(x \cdot y) \} \}$$

$$= \text{Min} \{ \inf m_{\alpha_{A \cap B}}^P(x \cdot z), \inf m_{\alpha_{A \cap B}}^P(x \cdot y) \}$$

Therefore $\inf m_{\alpha_{A \cap B}}^P(y \cdot z) \geq \text{Min} \{ \inf m_{\alpha_{A \cap B}}^P(x \cdot z), \inf m_{\alpha_{A \cap B}}^P(x \cdot y) \}$.

(iii) Now $\sup m_{\alpha_{A \cap B}}^N(y \cdot z) = \text{Max} \{ \sup m_{\alpha_A}^N(y \cdot z), \sup m_{\alpha_B}^N(y \cdot z) \}$

$$\leq \text{Max} \{ \text{Max} \{ \sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_A}^N(x \cdot y) \},$$

$$\text{Max} \{ \sup m_{\alpha_B}^N(x \cdot z), \sup m_{\alpha_B}^N(x \cdot y) \} \}$$

$$= \text{Max} \{ \text{Max} \{ \sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_B}^N(x \cdot z) \},$$

$$\text{Max} \{ \sup m_{\alpha_A}^N(x \cdot y), \sup m_{\alpha_B}^N(x \cdot y) \} \}$$

$$= \text{Max} \{ \sup m_{\alpha_{A \cap B}}^N(x \cdot z), \sup m_{\alpha_{A \cap B}}^N(x \cdot y) \}$$





Therefore $\sup m_{\alpha_{A \cap B}}^N(y \cdot z) \leq \text{Max}\{\sup m_{\alpha_{A \cap B}}^N(x \cdot z), \sup m_{\alpha_{A \cap B}}^N(x \cdot y)\}$.

(iv) Now $\inf n_{\alpha_{A \cap B}}^P(0) = \text{Max}\{\inf n_{\alpha_A}^P(0), \inf n_{\alpha_B}^P(0)\}$

$\leq \text{Max}\{\inf n_{\alpha_A}^P(x), \inf n_{\alpha_B}^P(x)\} = \inf n_{\alpha_{A \cap B}}^P(x)$

Therefore $\inf n_{\alpha_{A \cap B}}^P(0) \leq \inf n_{\alpha_{A \cap B}}^P(x)$.

Now $\sup n_{\alpha_{A \cap B}}^N(0) = \text{Min}\{\sup n_{\alpha_A}^N(0), \sup n_{\alpha_B}^N(0)\}$

$\geq \text{Min}\{\sup n_{\alpha_A}^N(x), \sup n_{\alpha_B}^N(x)\}$
 $= \sup n_{\alpha_{A \cap B}}^N(x)$

Therefore $\sup n_{\alpha_{A \cap B}}^N(0) \geq \sup n_{\alpha_{A \cap B}}^N(x)$.

(v) Now $\inf n_{\alpha_{A \cap B}}^P(y \cdot z) = \text{Max}\{\inf n_{\alpha_A}^P(y \cdot z), \inf n_{\alpha_B}^P(y \cdot z)\}$

$\leq \text{Max}\{\text{Max}\{\inf n_{\alpha_A}^P(x \cdot z), \inf n_{\alpha_A}^P(x \cdot y)\},$

$\text{Max}\{\inf n_{\alpha_B}^P(x \cdot z), \inf n_{\alpha_B}^P(x \cdot y)\}\}$

$= \text{Max}\{\text{Max}\{\inf n_{\alpha_A}^P(x \cdot z), \inf n_{\alpha_B}^P(x \cdot z)\},$

$\text{Max}\{\inf n_{\alpha_A}^P(x \cdot y), \inf n_{\alpha_B}^P(x \cdot y)\}\}$

$= \text{Max}\{\inf n_{\alpha_{A \cap B}}^P(x \cdot z), \inf n_{\alpha_{A \cap B}}^P(x \cdot y)\}$

Therefore $\inf n_{\alpha_{A \cap B}}^P(y \cdot z) \leq \text{Max}\{\inf n_{\alpha_{A \cap B}}^P(x \cdot z), \inf n_{\alpha_{A \cap B}}^P(x \cdot y)\}$.

(vi) Now $\sup n_{\alpha_{A \cap B}}^N(y \cdot z) = \text{Min}\{\sup n_{\alpha_A}^N(y \cdot z), \sup n_{\alpha_B}^N(y \cdot z)\} \geq \text{Min}\{\text{Min}\{\sup n_{\alpha_A}^N(x \cdot z), \sup n_{\alpha_A}^N(x \cdot y)\},$

$\text{Min}\{\sup n_{\alpha_B}^N(x \cdot z), \sup n_{\alpha_B}^N(x \cdot y)\}\} = \text{Min}\{\text{Min}\{\sup n_{\alpha_A}^N(x \cdot z), \sup n_{\alpha_B}^N(x \cdot z)\},$

$\text{Min}\{\sup n_{\alpha_A}^N(x \cdot y), \sup n_{\alpha_B}^N(x \cdot y)\}\} = \text{Min}\{\sup n_{\alpha_{A \cap B}}^N(x \cdot z), \sup n_{\alpha_{A \cap B}}^N(x \cdot y)\}$

Therefore $\sup n_{\alpha_{A \cap B}}^N(y \cdot z) \geq \text{Min}\{\sup n_{\alpha_{A \cap B}}^N(x \cdot z), \sup n_{\alpha_{A \cap B}}^N(x \cdot y)\}$.

Proposition:3.6

The union of any two sets are $\text{IVBIF}\alpha$ -ideal of a BP-algebra, if they are equal.

Proof:

We assume that

$0, x, y \in A \cup B \Rightarrow 0, x, y \in A \text{ or } 0, x, y \in B.$

(i) Now $\inf m_{\alpha_{A \cup B}}^P(0) = \text{Max}\{\inf m_{\alpha_A}^P(0), \inf m_{\alpha_B}^P(0)\}$

$\geq \text{Max}\{\inf m_{\alpha_A}^P(x), \inf m_{\alpha_B}^P(x)\}$

$= \inf m_{\alpha_{A \cup B}}^P(x)$

Therefore $\inf m_{\alpha_{A \cup B}}^P(0) \geq \inf m_{\alpha_{A \cup B}}^P(x)$.

Now $\sup m_{\alpha_{A \cup B}}^N(0) = \text{Min}\{\sup m_{\alpha_A}^N(0), \sup m_{\alpha_B}^N(0)\}$

$\leq \text{Min}\{\sup m_{\alpha_A}^N(x), \sup m_{\alpha_B}^N(x)\}$

$= \sup m_{\alpha_{A \cup B}}^N(x)$

Therefore $\sup m_{\alpha_{A \cup B}}^N(0) \leq \sup m_{\alpha_{A \cup B}}^N(x)$.

(ii) Now $\inf m_{\alpha_{A \cup B}}^P(y \cdot z) = \text{Max}\{\inf m_{\alpha_A}^P(y \cdot z), \inf m_{\alpha_B}^P(y \cdot z)\}$

$\geq \text{Max}\{\text{Min}\{\inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_A}^P(x \cdot y)\},$

$\text{Min}\{\inf m_{\alpha_B}^P(x \cdot z), \inf m_{\alpha_B}^P(x \cdot y)\}\}$

$= \text{Min}\{\text{Max}\{\inf m_{\alpha_A}^P(x \cdot z), \inf m_{\alpha_B}^P(x \cdot z)\},$

$\text{Max}\{\inf m_{\alpha_A}^P(x \cdot y), \inf m_{\alpha_B}^P(x \cdot y)\}\}$

$= \text{Min}\{\inf m_{\alpha_{A \cup B}}^P(x \cdot z), \inf m_{\alpha_{A \cup B}}^P(x \cdot y)\}$

Therefore $\inf m_{\alpha_{A \cup B}}^P(y \cdot z) \geq \text{Min}\{\inf m_{\alpha_{A \cup B}}^P(x \cdot z), \inf m_{\alpha_{A \cup B}}^P(x \cdot y)\}$.

(iii) Now $\sup m_{\alpha_{A \cup B}}^N(y \cdot z) = \text{Min}\{\sup m_{\alpha_A}^N(y \cdot z), \sup m_{\alpha_B}^N(y \cdot z)\}$

$\leq \text{Min}\{\text{Max}\{\sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_A}^N(x \cdot y)\},$

$\text{Max}\{\sup m_{\alpha_B}^N(x \cdot z), \sup m_{\alpha_B}^N(x \cdot y)\}\}$

$= \text{Max}\{\text{Min}\{\sup m_{\alpha_A}^N(x \cdot z), \sup m_{\alpha_B}^N(x \cdot z)\},$





$$\text{Min} \{ \sup m_{\alpha_A}^N(\mathbf{x} \cdot \mathbf{y}), \sup m_{\alpha_B}^N(\mathbf{x} \cdot \mathbf{y}) \}$$

$$= \text{Max} \{ \sup m_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{z}), \sup m_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{y}) \}$$

$$\text{Therefore } \sup m_{\alpha_{A \cup B}}^N(\mathbf{y} \cdot \mathbf{z}) \leq \text{Max} \{ \sup m_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{z}), \sup m_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{y}) \}.$$

$$(iv) \text{ Now } \inf n_{\alpha_{A \cup B}}^P(0) = \text{Min} \{ \inf n_{\alpha_A}^P(0), \inf n_{\alpha_B}^P(0) \}$$

$$\leq \text{Min} \{ \inf n_{\alpha_A}^P(x), \inf n_{\alpha_B}^P(x) \}$$

$$= \inf n_{\alpha_{A \cup B}}^P(x)$$

$$\text{Therefore } \inf n_{\alpha_{A \cup B}}^P(0) \leq \inf n_{\alpha_{A \cup B}}^P(x).$$

$$\text{Now } \sup n_{\alpha_{A \cup B}}^N(0) = \text{Max} \{ \sup n_{\alpha_A}^N(0), \sup n_{\alpha_B}^N(0) \}$$

$$\geq \text{Max} \{ \sup n_{\alpha_A}^N(x), \sup n_{\alpha_B}^N(x) \}$$

$$= \sup n_{\alpha_{A \cup B}}^N(x)$$

$$\text{Therefore } \sup n_{\alpha_{A \cup B}}^N(0) \geq \sup n_{\alpha_{A \cup B}}^N(x).$$

$$(v) \text{ Now } \inf n_{\alpha_{A \cup B}}^P(\mathbf{y} \cdot \mathbf{z}) = \text{Min} \{ \inf n_{\alpha_A}^P(\mathbf{y} \cdot \mathbf{z}), \inf n_{\alpha_B}^P(\mathbf{y} \cdot \mathbf{z}) \}$$

$$\leq \text{Min} \{ \text{Max} \{ \inf n_{\alpha_A}^P(\mathbf{x} \cdot \mathbf{z}), \inf n_{\alpha_A}^P(\mathbf{x} \cdot \mathbf{y}) \},$$

$$\text{Max} \{ \inf n_{\alpha_B}^P(\mathbf{x} \cdot \mathbf{z}), \inf n_{\alpha_B}^P(\mathbf{x} \cdot \mathbf{y}) \} \}$$

$$= \text{Max} \{ \text{Min} \{ \inf n_{\alpha_A}^P(\mathbf{x} \cdot \mathbf{z}), \inf n_{\alpha_B}^P(\mathbf{x} \cdot \mathbf{z}) \},$$

$$\text{Min} \{ \inf n_{\alpha_A}^P(\mathbf{x} \cdot \mathbf{y}), \inf n_{\alpha_B}^P(\mathbf{x} \cdot \mathbf{y}) \} \}$$

$$= \text{Max} \{ \inf n_{\alpha_{A \cup B}}^P(\mathbf{x} \cdot \mathbf{z}), \inf n_{\alpha_{A \cup B}}^P(\mathbf{x} \cdot \mathbf{y}) \}$$

$$\text{Therefore } \inf n_{\alpha_{A \cup B}}^P(\mathbf{y} \cdot \mathbf{z}) \leq \text{Max} \{ \inf n_{\alpha_{A \cup B}}^P(\mathbf{x} \cdot \mathbf{z}), \inf n_{\alpha_{A \cup B}}^P(\mathbf{x} \cdot \mathbf{y}) \}.$$

$$(vi) \text{ Now } \sup n_{\alpha_{A \cup B}}^N(\mathbf{y} \cdot \mathbf{z}) = \text{Max} \{ \sup n_{\alpha_A}^N(\mathbf{y} \cdot \mathbf{z}), \sup n_{\alpha_B}^N(\mathbf{y} \cdot \mathbf{z}) \} \geq \text{Max} \{ \text{Min} \{ \sup n_{\alpha_A}^N(\mathbf{x} \cdot \mathbf{z}), \sup n_{\alpha_A}^N(\mathbf{x} \cdot \mathbf{y}) \},$$

$$\text{Min} \{ \sup n_{\alpha_B}^N(\mathbf{x} \cdot \mathbf{z}), \sup n_{\alpha_B}^N(\mathbf{x} \cdot \mathbf{y}) \} \}$$

$$= \text{Min} \{ \text{Max} \{ \sup n_{\alpha_A}^N(\mathbf{x} \cdot \mathbf{z}), \sup n_{\alpha_B}^N(\mathbf{x} \cdot \mathbf{z}) \},$$

$$\text{Max} \{ \sup n_{\alpha_A}^N(\mathbf{x} \cdot \mathbf{y}), \sup n_{\alpha_B}^N(\mathbf{x} \cdot \mathbf{y}) \} \}$$

$$= \text{Min} \{ \sup n_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{z}), \sup n_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{y}) \}$$

$$\text{Therefore } \sup n_{\alpha_{A \cup B}}^N(\mathbf{y} \cdot \mathbf{z}) \geq \text{Min} \{ \sup n_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{z}), \sup n_{\alpha_{A \cup B}}^N(\mathbf{x} \cdot \mathbf{y}) \}.$$

We have given all the propositions which are proved here. On this topic "IVBIF ideal and IVBIF α -ideal", all the above propositions with proofs are also applicable for the operations on anti IVBIF ideal and anti IVBIF α -ideal.

CONCLUSION

Related to this topic new ideas are reflected effectively. A review about the operations were discussed with the significance of the new concepts. As the research has demonstrated some operations by giving the concrete ideas for further reference.

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An Overall Assessment of the HVAC System for Cleanroom Validation

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ABSTRACT

In a Pharmaceutical facility, properly designed, built, commissioned, operated, and maintained environmental control systems of Heating, Ventilation, and Air Conditioning systems ensure the products manufactured are of good quality and reduce both the initial and ongoing cost of ownership of a facility. The designing and qualification of the Heating, Ventilation, and Air Conditioning system to provide a safe and clean work environment in a pharmaceutical facility require additional considerations and compliance with regulatory bodies. Good Manufacturing Practices for Heating, Ventilation, and Air Conditioning services encompass various factors, including identifying crucial parameters such as temperature, humidity, pressure, air filtration, airflow patterns, and standard heating and cooling practices. In the design, specification, operation, and control of clean rooms and other controlled environments, it is important to take into account various factors beyond airborne particulate cleanliness. This paper briefly discusses the Operational Principles, Components, and Validation of Heating, Ventilation, and Air Conditioning Systems.

Keywords: Qualification, HEPA, airflow pattern, pharmaceutical facility, ISO





INTRODUCTION

The HVAC system in the pharmaceutical industry accounts for over 50% of energy usage in countries such as India. In the pharmaceutical industry, maintaining proper conditions in the manufacturing environment is crucial for producing safe and effective products, and the U.S. FDA regulates the industry through the c GMP (current Good Manufacturing Practices).[1] Building Management System (BMS) is an essential tool and it enables optimal building performance by reducing loads and operating hours, thus extending the lifespan of equipment and systems, reducing maintenance and capital costs, and minimizing the use of energy for replacements and upgrades. Pharmaceutical validation of HVAC systems provides appropriate temperature, ventilation, and air conditioning to achieve quality drug products. The design of the HVAC system has a major role in the prevention and control of cross-contamination by maintaining a clean environment. The critical parameters such as temperature and ventilation are maintained during processing and finished product storage [2,3]ASHRAE states, "HVAC system must achieve controlling air temperature, air humidity, air circulation, and air quality".[4]

Operational principle

In the pharmaceutical industry, HVAC systems must keep pace with advancements in science and technology. To maintain a clean room with clean air quality HVAC should be interconnected and the cost for installation, operation, and maintenance should be reasonable. HVAC systems perform four functions: controlling airborne particles, maintaining room pressure, managing room moisture, and regulating room temperature. To prevent airborne contamination, cleaner areas are kept under positive pressure, which means that more air is brought into the area than is allowed to escape. In addition, humidity and temperature must be controlled to prevent the growth of microbial contaminants and to maintain drug efficacy and stability.[5,6] Air handling unit (AHU)- Air handler is a large metal box usually galvanized for long-term protection with several components such as filter racks, heating or cooling coil, blower, sound attenuators, and dampers. The design of the AHU ensures that both the incoming fresh air and the return air pass through the filter before reaching the downstream components connected to the ductwork, which then distributes the clean air throughout the building. It is important to note that HVAC systems cannot replace good processes, facility and equipment design, or proper operating procedures. These systems are incapable of effectively cleaning surfaces that are already contaminated, controlling processes that produce excessive contaminants, or compensating for inadequately designed or maintained facilities. While HVAC systems can help control biocontamination by delivering clean air to a room, they cannot eliminate biocontamination. Persistent contamination problems are unlikely to be caused or resolved by an HVAC system that has not been appropriately designed, constructed, or maintained.[6,7]

Air-Flow pattern

Clean rooms can be classified based on the air supply configuration, such as non-unidirectional airflow and unidirectional airflow.

Non-Unidirectional Air Flow

Non-unidirectional airflow is a type of airflow pattern that generates significant turbulence and is suitable for rooms where external sources are expected to cause significant contamination. The uniformity of particle concentration, required for the process, is achieved through the mixing of high and low particle concentrations facilitated by turbulence. In Non-unidirectional airflow rooms cleanliness of level Class 1000 to Class 100,000 can be attained.

Unidirectional Airflow

In a unidirectional airflow pattern, the air flows in a single direction of parallel streams, which is also known as 'laminar' airflow, with some angular deviation. Clean rooms of this type are employed in situations where there is a requirement for low levels of airborne contaminants, and where the primary concern is internal contaminants. In vertical down-flow clean rooms, the air moves in a vertical direction, and in horizontal-flow clean rooms, the air moves in a horizontal direction. Vertical down-flow is generally preferred in pharmaceutical production processes.



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Clean rooms require strict control of temperature, humidity, particle counts, airflow patterns, and differential pressure. They require an increased air supply, with 50-100 air changes for a Class 10,000 clean room. High-efficient filtration of 99.97% down to 0.3 microns of HEPA filters is used, and a laminar flow is sought.[7-9]

Validation of HVAC System

Validating an HVAC system involves compiling essential documents, including functional specifications, design drawings, validation plans, contractor documents, TAB reports, start-up reports, commissioning reports, and validation documents such as IQ, OQ, and PQ.

Design Qualification

On completion of the DQ activity, there should be no deviation in the design specification; thereby, the system can be installed, and IQ activities can be carried out.[8,9]

Installation Qualification

Ensure that the HVAC System is installed at the designated place with the correct material of construction (MOC) for all the critical parts. Ensure that all safety features are installed. Verify additional information in accordance with the protocol's guidelines, then record your observations. When installing the HVAC system, compare the installation qualification parameters to the manufacturer's recommendations. If there is a deviation of any kind, note it and take the necessary action. Whether or not the deviation is acceptable will be determined by the head of the department and the head of quality assurance. Start the operation qualification process if the deviation is acceptable and has no chance of affecting operation. If the deviation is unacceptable, let the head of the department in question know so that the appropriate steps can be taken to address the issues and finish the installation qualification. Verification of installed equipment with suitable utility connections, major components as per the design specifications, completion of the installation as per manufacturer's recommendations & cGMP requirements, and the supply of all necessary documentation from the manufacturer takes the HVAC system for OQ.

Operational Qualification

The purpose of OQ is to verify that systems operate by specifications and to document all pertinent information and data to showcase their expected functionality. The verification of operational qualification parameters such as the operation of the fan section and its respected motors and blowers, operation of the chilled water coil and verification of its function as it gives cool air when passed through it, operation of dampers as it moves freely and allow air to pass through when open and restrict the entry of air when closed, operation of Magnehelic gauge verification that Magnehelic gauge installed outside the area is functional when AHU is started followed by general functionality test verification such as alignment, interlock, AHU performance, power failure test verification, control panel verification and maintenance parameters. The OQ parameters are verified and the system can be taken for PQ.[9]

Performance Qualification: PQ aims to demonstrate, through test results, that the system and its components consistently meet specifications during regular use.[10] Ensure that the HVAC system has been operating for a minimum of 24 hours and is stable. The tests shall be carried out at the REST condition of the room to validate the installed HVAC system and the clean room.

Air velocity test at terminal HEPA filter

Check and record the main duct supply CFM of the AHU and transfer the anemometer inside the area hold the anemometer downstream of the Mini Pleat HEPA filter face at a distance of one inch and allow the reading to stabilize for 20 seconds. Fluctuation should not be more than ± 5 FPM. Take five readings (at four corners and one centre point) and report the individual and average velocity. The measured average velocity should be within the limit of 90 fpm $\pm 20\%$ i.e., 72-108 fpm (unidirectional airflow). Velocity differences within the same plenum should not vary more than 25% fpm.[8,9]





Leak testing of terminal HEPA filter

Use an appropriate number of nozzles to challenge and maintain a concentration between 15 µg and 80 µg of PAO per L of air at the upstream side of the Mini Pleat HEPA filter. Set the compressed air supply to the PAO aerosol generator between 20 psig and 25 psig & challenge the suction side of the AHU with the PAO aerosol. Transfer the PAO photometer inside the area. Adjust the photometer to read 100% and ensure that the detector is functioning properly when exposed to PAO aerosol at the upstream side of the Mini Pleat HEPA filter. Hold the detector probe approximately one inch downstream of the Mini Pleat HEPA filter face under test and scan the entire perimeter and face area of the filter at a perpendicular rate of a maximum of 10 ft/min for locating any leakages through the Mini Pleat HEPA filter. Leakages are detected and noticed by the beep noise produced due to PAO sensing. At the end of the PAO test of a Mini Pleat HEPA filter, ensure that the upstream concentration of the PAO remains between 90% and 110% of the set value (between 15 µg/L of air and 80 µg/L of air). Any leakage of aerosol greater than 0.01% is considered unacceptable and warrants replacement and re-testing.[10]

Air Changes Per Hour Test (ACPH)

This procedure is only applicable for non-unidirectional or mixed airflow patterns. Using the measuring tape, the length and width of the Mini Pleat HEPA filter are measured in feet. Report the average velocity of each Mini Pleat HEPA filter.¹¹ Calculate the ACPH by the formula:

HEPA CMH = Air velocity in meter × Filter face area in meter

Total CMH = \sum HEPA CMH

Air changes per hour = $\frac{\text{Total CMH} \times 60}{\text{Volume of room in cubic ft.}}$

Air changes obtained for the room should not be less than the limit as shown in Table1.

Airborne Particle Count Test

At rest condition, the particle count should be taken. Predetermine the location for the particle counting before entering the area. Transfer the clean Met One counter to the area. The apparatus is cleaned by wiping the surface with a lint-free cloth. Connect the iso-kinetic probe to the sensor inlet. Carry out the airborne particle counting at a defined location at a working height of 900 mm from the finished floor level. Record the observations.[11-13] The air system can be considered validated when the results of the test are within the acceptable operational parameters as shown in Table2.

Area recovery test

To determine the placement of the particle counter, identify the spot with the highest particle count in the clean room under resting conditions. Position the sampling probe vertically upward, ensuring it is not placed directly under the air outlet. The sample volume should match the volume used to determine the cleanliness class. Take an initial reading of the room L × W × H for enumeration of particles of >0.5µ and > 5.0µ particles, temperature, RH. To assess the clean room area, an Aerosol generator is used to intentionally contaminate it to a particle concentration 100 times higher than the target cleanliness level. This is achieved by raising the particle concentration in the area while the air handling unit is operational. Start the particle count monitoring at an interval of 1 minute until the particles reach approx. 100 times (t_{100n}) more than the initial particle count of the area. Stop generating particles through an aerosol generator once the area reaches more than the specified class. Take the samples at an interval of 1 minute and it shall be continued till the time point (t_n) at which the desired level of cleanliness (approx. initial particle count reading) is achieved. $t_{0.01} = (t_n - t_{100n})$ represents the 100:1 recovery time. Room recovery state is however not mandatory for Class B. The recovery time for the cleanroom to regain the specified cleanliness class level when exposed to PAO aerosol should be no more than 15 minutes.[10, 11, 14]

Airflow pattern test

Generate the smoke with a Smoke generator using the water glycerine mixture. Introduce the smoke downstream of the HEPA filter. Observe the airflow pattern and record the airflow direction in the rooms using digital videography, under terminal HEPA Filters, and risers, with the doors of the room both in open and closed Condition. The airflow





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is considered acceptable only if it shows flow as per the design specification. If the smoke flows in the opposite direction, then corrective changes are necessary. The flow direction between rooms shall be as per the room pressure cascading design.[14]

Temperature & humidity uniformity test

Monitoring temperature & humidity daily with the help of a thermometer and manometer respectively; stabilization of both parameters is ensured within the specified limit.

Pressure difference

A pressure difference of 5 to 20mmHg pressure is usually maintained and it is calculated using a manometer which is attached to the walls of the adjacent area.

CONCLUSION

To achieve a clean room and controlled environment in a pharmaceutical facility; planning, designing, and commissioning activities of the HVAC system before installation plays a major role in successful IQ, OQ, and PQ. By performing the above-discussed tests for validation of the HVAC system at an appropriate frequency of testing and if the tests meet the acceptance criteria, then the HVAC system can be qualified for daily routine use and the results are documented.

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Table.1: Acceptance Criteria For Air Changes Per Hour

Class	Air changes per hour
ISO CLASS 6	Not less than 40
ISO CLASS 7	Not less than 20
ISO CLASS 8	Not less than 20
Controlled Non-Classified	Not less than 10

Table.2: ISO Classes of Air Cleanliness By Particle Concentration

Class	The maximum permitted number of particles/m ³			
	at rest		in operation	
	≥ 0.5 µm	≥ 5.0 µm	≥ 0.5 µm	≥ 5.0 µm
ISO Class 5 (Class 100)	3,520	29	3,520	29
ISO Class 6(Class 1000)	35,200	293	3,52,000	2,930
ISO Class 7(Class 10,000)	3,52,000	2,930	35,20,000	29,300
ISO Class 8(Class 1,00,000)	35,20,000	29,300	Not Defined	Not Defined





Topological Indices of Dutch Windmill (m -fan) Fuzzy Random Graph

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ABSTRACT

study explores the topological indices of m -fan fuzzy random graphs, a novel class of graphs characterized by both fuzzy and random components. Also this study extends traditional graph theory by integrating fuzzy set theory with random graph models, thereby enriching the study of graph properties in uncertain environments. The m -fan fuzzy random graph is constructed by introducing fuzzy probabilities to the edges of an m -fan graph, which allows for a nuanced representation of edge existence and connectivity. Furthermore, this research focuses on several key topological indices, including the Zagreb indices and the Randic index, to assess the structural properties of these graphs, and this analysis provides explicit formulas and bounds for these indices, taking into account the fuzzy randomness associated with edge probabilities. This study adds to the fields of fuzzy graph theory, random graph models, and complex network analysis by helping us understand how deterministic and stochastic factors affect the topological properties of graphs.

Keywords: Fuzzy graphs, Random graphs, Fuzzy random graph, Dutch windmill (m -fan) graph, Topological indices.





INTRODUCTION

In recent years, the intersection of graph theory and fuzzy logic has yielded fascinating advancements in understanding complex systems. One particularly intriguing development is the concept of Dutch Windmill fuzzy random graphs. This model integrates the structural elegance of Dutch windmill-inspired graphs with the nuanced flexibility of fuzzy logic, offering a novel approach to analyzing networks with inherent uncertainties. The Dutch Windmill graph is inspired by the symmetric, interconnected layout of traditional Dutch windmills. In the context of graph theory, this translates into a highly regular and aesthetically appealing structure with distinct patterns of connectivity. However, real-world networks often involve uncertainties and imprecisions that simple deterministic models cannot adequately address. This is where fuzzy logic becomes crucial. Fuzzy logic allows for the representation of partial truths and uncertainty, enabling a more nuanced approach to modeling relationships between nodes. By combining fuzzy logic with the Dutch Windmill graph, we obtain a "Dutch Windmill Fuzzy Random Graph" that not only captures the geometric elegance of windmill-inspired designs but also accommodates the variability and imprecision of real-world data. In "The First And Second Zagreb Indices Of Degree Splitting Of Molecular Graphs"**(1)**, Mrs. Ragavi focuses on calculating these indices for molecular graphs, which represent structures like silicate networks and honeycomb networks, particularly when these graphs undergo a process called degree splitting. Various topological indices—numerical values that characterize the structure of fuzzy graphs—such as the Modified Wiener Index and others—and it explores their applications in fields like chemistry and computer science are defined in "Some topological indices in fuzzy graphs"**(2)**. Kale, Mahesh, and S. Minirani introduce new concepts related to fuzzy graphs, which account for uncertainty in relationships, and explore the associated Zagreb matrices and energies, providing bounds for these energies to enhance understanding of fuzzy graph properties**(3)**. Several indices related to bipolar fuzzy graphs, including the first and second Zagreb indices, the Randic index, and others, exploring their mathematical properties like union and intersection, are discussed **(4)**. The authors Shetty, Shashwath S, and Arathi Bhat K. explore how adding self-loops to certain vertices in a graph affects the first Zagreb index and provide specific limits for this index when self-loops are present**(5)**.

The articles explore the use of the F-index for fuzzy graphs to analyze railway crimes, showing that it offers more realistic results compared to other methods, and discuss various mathematical operations and properties related to fuzzy graphs that can help in understanding these crime patterns**(6)**, **(7)**. Mufti, Zeeshan Saleem, et al. calculated specific fuzzy topological indices for a structure called the pizza graph, which is a type of graph used in mathematics**(8)**. They found general results for these indices, which can enhance our understanding of how these mathematical concepts apply to real-world problems. "Evaluation of Various Topological Indices of Flabellum Graphs"**(9)** focuses on flabellum graphs, which are created by duplicating a cycle graph and adding connections to a central vertex, and explores various mathematical properties called topological indices that help analyze these graphs. Fuzzy topological indices for flower graphs, which are numerical values that help characterize the properties of these graphs, enhancing our understanding of fuzziness in general graph theory, are found **(10)**. The researchers Sarala N. and Abirami R. aim to understand how different operations, like combining or intersecting these graphs, affect their topological indices, which are numerical values that describe the graph's structure**(11)**. Islam, SkRabiul, Bandar Bin Mohsin, and Madhumangal Pal introduce a new version called the hyper-ZI specifically for fuzzy graphs, which can represent uncertain information. The researchers calculate the hyper-ZI for different types of fuzzy graphs and find that it can effectively compare with other indices when analyzing crime data, showing better performance in reflecting real-world situations**(12)**. In this study, we investigate the topological indices of certain fuzzy random graphs, namely Dutch windmills of m -fan fuzzy random graphs, and analyze their topological indices.

PRELIMINARIES

Definition: 2.1

Let $\mathbb{V}_{\mathcal{FR}} = \{v_i, i = 1, 2, \dots, n\}$ be a set of n vertices has $n(n-1)/2$ possible edges $\mathbb{E}_{\mathcal{FR}}$ between them. Then there are two sets of edges,





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$\mathbb{E}_{\mathcal{F}} = \{(v_i, v_j) / 1 \leq v_i < v_j \leq n; i, j = 1, 2, \dots, n \text{ and } (v_i, v_j) \text{ are fuzzy edges}\},$
 $\mathbb{E}_{\mathcal{R}} = \{(v_i, v_j) / 1 \leq v_i < v_j \leq n; i, j = 1, 2, \dots, n \text{ and } (v_i, v_j) \text{ are random edges}\}$ that are disjoint. Consider the mapping $\phi_g: \mathbb{V}_{\mathcal{FR}} \rightarrow [0,1] v_i \rightarrow \phi_g(v_i)$
 $\psi_g: \mathbb{V}_{\mathcal{FR}} \times \mathbb{V}_{\mathcal{FR}} \rightarrow [0,1]_P \times [0,1]_{f_A}$
 $(v_i, v_j) \rightarrow \psi_g(v_i, v_j) = (P(v_i, v_j), f_A(v_i, v_j))$
 with $P(v_i, v_j) = 0$ if and only if $f_A(v_i, v_j) = 0$. Then the quartet $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is called a fuzzy random graph if $\psi_g(v_i, v_j) \leq \min\{\phi_g(v_i), \phi_g(v_j)\}$ where (v_i, v_j) corresponds to the edge between v_i and v_j , $P(v_i, v_j)$ and $f_A(v_i, v_j)$ represents the probability of the edge (v_i, v_j) and the membership function for the edge (v_i, v_j) within the fuzzy set A in X respectively.

Definition: 2.2

A fuzzy random graph $\mathbb{H}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is called a partial fuzzy random subgraph of $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ if $\tau_g(v_i) \leq \phi_g(v_i)$ for every $v_i \in \mathbb{V}_{\mathcal{FR}}$ and $\sigma_g(v_i, v_j) \leq \psi_g(v_i, v_j)$ for every $(v_i, v_j) \in \mathbb{E}_{\mathcal{FR}}$. Also the fuzzy random graph $\mathbb{H}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is called a fuzzy random subgraph of $\mathbb{G}_{\mathcal{FR}}$ induced by α if $\alpha \subseteq \mathbb{V}_{\mathcal{FR}}$, $\tau_g(v_i) = \phi_g(v_i)$ for all $v_i \in \alpha$ and $\sigma_g(v_i, v_j) = \psi_g(v_i, v_j)$ for all $(v_i, v_j) \in \alpha$. We write $\langle \alpha \rangle$ to denote the fuzzy random subgraph induced by α .

Definition: 2.3

Let $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ be a fuzzy random graph. Then a partial fuzzy random subgraph $\mathbb{H}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ of $\mathbb{G}_{\mathcal{FR}}$ is said to span $\mathbb{G}_{\mathcal{FR}}$ if $\tau_g = \phi_g$. Here $\mathbb{H}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is called spanning fuzzy random subgraph of $\mathbb{G}_{\mathcal{FR}}$.

Definition: 2.4

In a fuzzy random graph $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$, the degree of a fuzzy random vertex v_i is defined as

$$d_{\mathbb{G}_{\mathcal{FR}}}(v_i) = \sum_{v_i \neq v_j \in \mathbb{E}_{\mathcal{FR}}} \psi_g(v_i, v_j) + \sum_{v_i \neq v_j \in \mathbb{E}_{\mathcal{R}}} nP$$

for $(v_i, v_j) \in \mathbb{E}_{\mathcal{FR}}$ and $\psi_g(v_i, v_j) = 0$ for (v_i, v_j) not in $\mathbb{E}_{\mathcal{FR}}$. Where $\psi_g(v_i, v_j) = P$

$$d_{\mathbb{G}_{\mathcal{FR}}}(v_i) = \sum_{v_i, v_j \in \mathbb{E}_{\mathcal{FR}}} \psi_g(v_i, v_j) + \sum_{v_i, v_j \in \mathbb{E}_{\mathcal{R}}} n\psi_g(v_i, v_j)$$

Definition: 2.5

The Minimal degree of vertex, $\delta(\mathbb{G}_{\mathcal{FR}}) = \min \{d_{\mathbb{G}_{\mathcal{FR}}}(v_i, v_j) : (v_i, v_j) \in \mathbb{E}_{\mathcal{FR}}\}$

The Maximal degree of vertex, $\Delta(\mathbb{G}_{\mathcal{FR}}) = \max \{d_{\mathbb{G}_{\mathcal{FR}}}(v_i, v_j) : (v_i, v_j) \in \mathbb{E}_{\mathcal{FR}}\}$

Definition: 2.6

The order $\mathcal{O}(\mathbb{G}_{\mathcal{FR}})$ and size $\mathcal{S}(\mathbb{G}_{\mathcal{FR}})$ of fuzzy random graph $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is defined as, $\mathcal{O}(\mathbb{G}_{\mathcal{FR}}) = \sum \phi_g(v_i), v_i \in \mathbb{V}_{\mathcal{FR}}$, $\mathcal{S}(\mathbb{G}_{\mathcal{FR}}) = \sum \psi_g(v_i, v_j), (v_i, v_j) \in \mathbb{E}_{\mathcal{FR}}$

Definition: 2.7

The fuzzy random graph $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is called a complete fuzzy random graph if $\psi_g(v_i, v_j) = \min\{\phi_g(v_i), \phi_g(v_j)\}$ for all $(v_i, v_j) \in \mathbb{E}_{\mathcal{FR}}$.

Definition: 2.8

A fuzzy random graph $\mathbb{G}_{\mathcal{FR}} = (\mathbb{V}_{\mathcal{FR}}, \mathbb{E}_{\mathcal{FR}})$ is connected if any two vertices are joined by a path.

Definition: 2.9

Zagreb index of fuzzy random graph is given by





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$$M(G) = \sum_{u_i \in V} u_i d^2(u_i) \text{ for all } u_i \in V$$

$$M^*(G) = \frac{1}{2} \sum_{u_i, v_i \in V} \sigma(u_i) d(u_i) \sigma(v_i) d(v_i) + \sum_{uv \in E} d(u) d(v)$$

where $d(u_i)$ - degree of vertex

Definition:2.10

Randic connectivity index of fuzzy random graph

$$R(G) = \sum_{uv \in E} \frac{1}{\sqrt{d(u)d(v)}} + \frac{1}{2} \sum \frac{1}{\sqrt{\sigma(u_i)d(u_i)\sigma(v_j)d(v_j)}}$$

where uv -edge, du, dv are degree of vertices u and v .

Definition:2.11

Harmonic index of fuzzy random graph

$$H(G) = \frac{1}{2} \sum_{u_i, v_i \in V} \frac{1}{\sigma(u_i)d(u_i) + \sigma(v_j)d(v_j)} + \sum \frac{2}{du + dv}$$

METHODOLOGY**Dutch windmill graph or m -fan fuzzy random graph**

In graph theory, a friendship graph is a type of graph where each vertex represents a person, and an edge between two vertices represents a friendship between those two people. A common example is a "triangle" graph where each person is friends with two others, forming a triangle. More generally, friendship graphs can be complex but often have properties related to cliques and triangles. Friendship relationships are represented in a graph. The presence or strength of these friendships is fuzzy, meaning the relationships can vary in strength rather than being strictly present or absent. The graph itself is generated or evolves based on some random process, where the probability of an edge being fuzzy is influenced by random factors. In practical terms, such a model could be used to study social networks where friendships vary in strength and evolve over time in a probabilistic manner. It could be useful in fields like sociology, computer science, or any area where understanding complex, probabilistic relationships is important. In an n -fan graph, the structure involves a central vertex connected to all other vertices, which are then connected in a radial manner.

 m -fan fuzzy random graph

Let's break down the problem involving the n -fan fuzzy random graph $G_{F_m} = (V_{F_m}, E_{F_m})$ where each vertex and edge have specific membership values, and analyze the degrees of the vertices.

Vertices and Edges

Each vertex in G_{F_m} has a membership value of 0.5.

Each edge in G_{F_m} has a membership or probability value of 0.4.

Degrees

Each vertex (except the middle vertex) has a degree of 1.2.

The middle vertex has a degree of 0.8m.

For vertices, the degree mentioned (1.2 for non-middle vertices and 0.8m for the middle vertex) likely means the expected number of edges connected to each vertex in a fuzzy sense. This would be consistent with the idea that the graph is "fuzzy" or probabilistic.





DISCUSSION

Zagreb indices of m -fan fuzzy random graph

First Zagreb index of m -fan fuzzy random graph

$$M(G) = \sum_{u_i \in \sigma} u_i d^2(u_i) \text{ for all } u_i \in V$$

The 1-fan fuzzy random graph is given by

$$M(G) = \sum_{u_i \in \sigma} u_i d^2(u_i) \text{ for all } u_i \in V$$

$$M(G) = (0.5)(1.2)^2 + (0.5)(1.2)^2 + (0.5)(0.8)^2 = 1.76$$

Theorem: 4.1

Let $G_{F_m} = (V_{F_m}, E_{F_m})$ be a m -fan fuzzy random graph, then the first zagreb index of the m -fan fuzzy random graph is $M(G) = 0.32m^2 + 1.44m$

Proof

Let $G_{F_m} = (V_{F_m}, E_{F_m})$ be a m -fan fuzzy random graph with vertex and edge has membership values 0.5 and 0.4 respectively. Then it implies that degree of middle vertex is $0.8m$ while all the other vertices have 1.2 degree.

$$M(G) = \sum_{u_i \in \sigma} u_i d^2(u_i) \text{ for all } u_i \in V$$

$$M(G) = 2m(0.5)(1.2)^2 + (0.5)(0.8m)^2$$

$$M(G) = (0.5)[2m(1.2)^2 + (0.8m)^2]$$

$$M(G) = 0.32m^2 + 1.44m$$

Remark

For $m = 2$, $M(G) = 0.32(2)^2 + 1.44(2) = 4.16$

For $m = 3$, $M(G) = 0.32(3)^2 + 1.44(3) = 7.2$

For $m = 4$, $M(G) = 0.32(4)^2 + 1.44(4) = 10.88$

Second Zagreb index of m -fan fuzzy random graph:

$$M^*(G) = \frac{1}{2} \sum_{u_i, v_i \in \mu} \sigma(u_i)d(u_i)\sigma(v_i)d(v_i) + \sum_{uv \in E} d(u)d(v)$$

$$\text{For } m = 1, M^*(G) = \frac{1}{2} [(0.5)(1.2)(0.5)(0.8) + (0.5)(1.2)(0.5)(0.8)] + (1.2)^2$$

$$M^*(G) = \frac{1}{2} [(0.5)(1.2)(0.5)(0.8)^2] + (1.2)^2 = 1.68$$

Theorem: 4.2

Let $G_{F_m} = (V_{F_m}, E_{F_m})$ be a m -fan fuzzy random graph, then the second zagreb index of the m -fan fuzzy random graph is $M^*(G) = 0.24m^2 + 1.44m$

Proof

$$M^*(G) = \frac{1}{2} \sum_{u_i, v_i \in \mu} \sigma(u_i)d(u_i)\sigma(v_i)d(v_i) + \sum_{uv \in E} d(u)d(v)$$

$$M^*(G) = \frac{1}{2} (2m)[(0.5)(1.2)(0.5)(0.8m)] + m(1.2)^2$$

$$M^*(G) = (m)[(0.5)(1.2)(0.5)(0.8m)] + 1.44m$$





$$M^*(G) = 0.24m^2 + 1.44m$$

Remark

For $m = 2, M^*(G) = 3.84$

For $m = 3, M^*(G) = 6.48$

For $m = 4, M^*(G) = 9.60$

Randic index of m -fan fuzzy random graph

$$R(G) = \frac{1}{2} \sum \frac{1}{\sqrt{\sigma(u_i)d(u_i)\sigma(v_j)d(v_j)}} + \sum_{uv \in E} \frac{1}{\sqrt{dudv}}$$

For $m = 1,$

$$R(G) = \frac{1}{2} \sum \frac{1}{\sqrt{\sigma(u_i)d(u_i)\sigma(v_j)d(v_j)}} + \sum_{uv \in E} \frac{1}{\sqrt{dudv}}$$

$$R(G) = \frac{1}{2} \left\{ \frac{1}{\sqrt{((0.5)(1.2)(0.5)(0.8))}} + \frac{1}{\sqrt{((0.5)(1.2)(0.5)(0.8))}} \right\} + \frac{1}{\sqrt{((1.2)(1.2))}}$$

$$R(G) = \frac{1}{2} \left\{ \frac{1}{\sqrt{(0.24)}} + \frac{1}{\sqrt{(0.24)}} \right\} + \frac{1}{\sqrt{(1.44)}} = 2.875$$

Theorem: 4.3

Let $G_{F_m} = (V_{F_m}, E_{F_m})$ be a m -fan fuzzy random graph, then the second zagreb index of the m -fan fuzzy random graph is $R(G) = \frac{m}{\sqrt{0.24m}} + \frac{1}{\sqrt{1.44m}}$

Proof

$$R(G) = \frac{1}{2} \sum \frac{1}{\sqrt{\sigma(u_i)d(u_i)\sigma(v_j)d(v_j)}} + \sum_{uv \in E} \frac{1}{\sqrt{dudv}}$$

$$R(G) = \frac{1}{2} \left\{ \frac{1}{\sqrt{((0.5)(1.2)(0.5)(0.8))}} + \frac{1}{\sqrt{((0.5)(1.2)(0.5)(0.8))}} \right\} + \frac{1}{\sqrt{((1.2)(1.2))}}$$

$$R(G) = \frac{1}{2} \left\{ \frac{2m}{\sqrt{((0.5)(1.2)(0.5)(0.8m))}} \right\} + \frac{1}{\sqrt{((1.2)(1.2)m)}}$$

$$R(G) = \left\{ \frac{m}{\sqrt{(0.24m)}} \right\} + \frac{1}{\sqrt{(1.44m)}}$$

For $m = 2,$

$$R(G) = \left\{ \frac{2}{\sqrt{(0.24(2))}} \right\} + \frac{1}{\sqrt{(1.44(2))}} = 3.476$$

For $m = 3,$

$$R(G) = \left\{ \frac{3}{\sqrt{(0.24(3))}} \right\} + \frac{1}{\sqrt{(1.44(3))}} = 4.017$$

For $m = 4,$

$$R(G) = \left\{ \frac{4}{\sqrt{(0.24(4))}} \right\} + \frac{1}{\sqrt{(1.44(4))}} = 4.499$$





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Harmonic index of m -fan fuzzy random graph:

$$H(G) = \frac{1}{2} \sum_{u_i, v_i \in \mu} \frac{1}{\sigma(u_i)d(u_i) + \sigma(u_j)d(u_j)} + \sum \frac{2}{du + dv}$$

For $m = 1$,

$$H(G) = \frac{1}{2} \left\{ \frac{1}{(0.5)(1.2) + (0.5)(0.8)} + \frac{1}{(0.5)(1.2) + (0.5)(0.8)} \right\} + \frac{2}{(1.2) + (1.2)}$$

$$H(G) = \frac{1}{2} \left\{ \frac{2}{(0.6) + (0.4)} \right\} + \frac{2}{2.4}$$

$$H(G) = 1 + \frac{1}{1.2} = 1.833$$

Theorem: 4.4

Let $G_{F_m} = (V_{F_m}, E_{F_m})$ be a m -fan fuzzy random graph, then the second zagreb index of the m -fan fuzzy random graph is $H(G) = \frac{m}{0.6+0.4m} + \frac{m}{1.2}$

Proof

$$H(G) = \frac{1}{2} \left\{ \frac{1}{(0.5)(1.2) + (0.5)(0.8)} + \frac{1}{(0.5)(1.2) + (0.5)(0.8)} \right\} + \frac{2}{(1.2) + (1.2)}$$

$$H(G) = \frac{1}{2} \left\{ \frac{2m}{(0.5)(1.2) + (0.5)(0.8m)} \right\} + \frac{2m}{2.4}$$

$$H(G) = \left\{ \frac{m}{0.6 + 0.4m} \right\} + \frac{m}{1.2}$$

For $m = 2$,

$$H(G) = \left\{ \frac{2}{0.6 + 0.4(2)} \right\} + \frac{2}{1.2} = 3.095$$

For $m = 3$,

$$H(G) = \left\{ \frac{3}{0.6 + 0.4(3)} \right\} + \frac{3}{1.2} = 4.167$$

For $m = 4$,

$$H(G) = \left\{ \frac{4}{0.6 + 0.4(4)} \right\} + \frac{4}{1.2} = 5.152$$

CONCLUSION

This study delves into the computation of the topological indices such as the first Zagreb index, the second Zagreb index, the Randic index, and the Harmonic index for the m -fan fuzzy random graph. By applying the formulae defined in the preliminaries, this study demonstrates that each of these indices can be accurately calculated for this specific graph model. The research involves a detailed comparison of the m -fan fuzzy random graph with other graph types, as presented in the accompanying tables and graphical representations. The findings reveal that the m -fan fuzzy random graph exhibits distinct properties in terms of these topological indices, offering a deeper understanding of its structural characteristics. This study not only enhances the theoretical framework surrounding fuzzy random graphs but also provides practical insights for applications in network analysis and related fields.



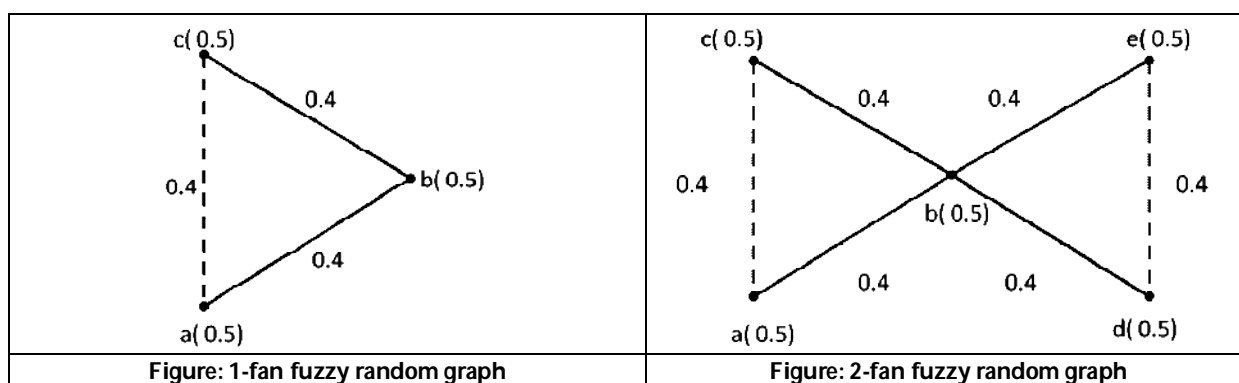


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Table.1 The comparison of topological indices of m -fan fuzzy random graphs

Topological Indices of m -fan fuzzy random graph	First Zagreb Index	Second Zagreb Index	Randic Index	Harmonic Index
$m = 1$	1.76	1.68	2.88	1.83
$m = 2$	4.16	3.84	3.48	3.10
$m = 3$	7.20	6.48	4.02	4.17
$m = 4$	10.88	9.60	4.50	5.15





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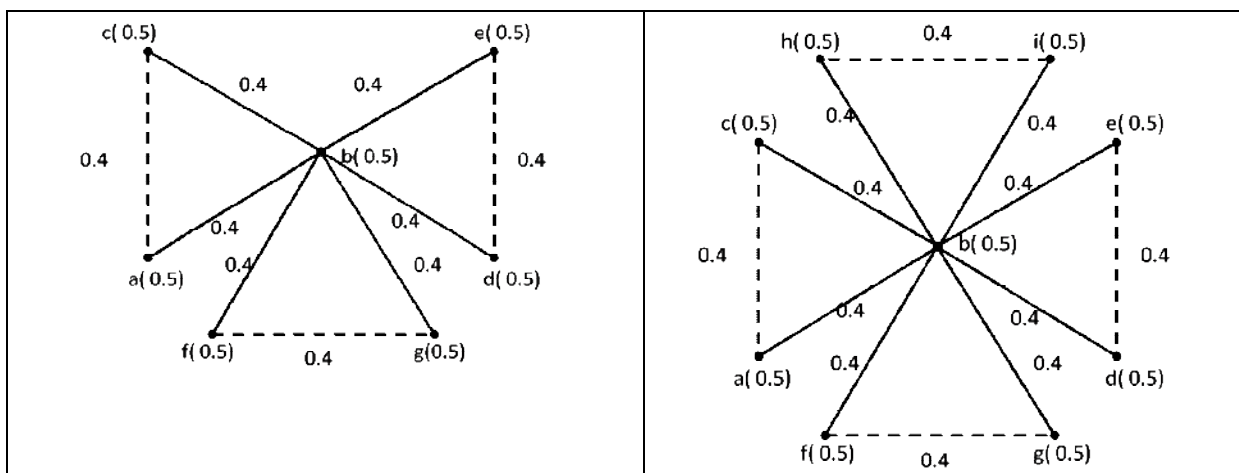


Figure: 3-fan fuzzy random graph

Figure: 4-fan fuzzy random graph

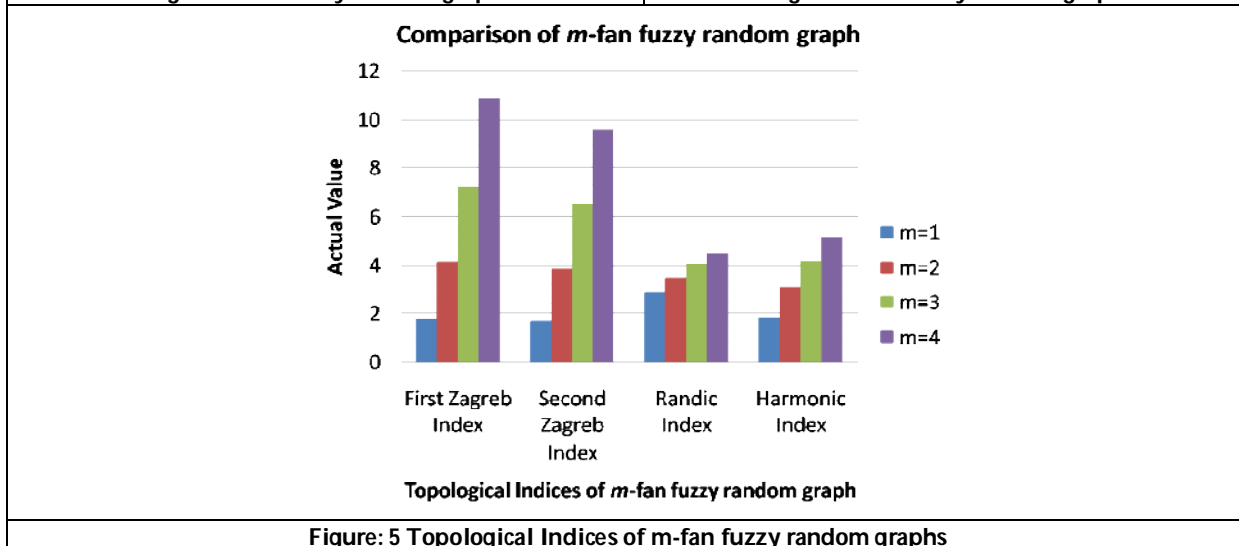


Figure: 5 Topological Indices of m -fan fuzzy random graphs





Kala in Ayurveda: A Comprehensive Study of Membranes and their Functions

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ABSTRACT

Anatomy, the branch of science that studies the various structures of the human body. In Ayurvedic anatomy, "Kala Sharir" is a significant concept, referring to the layers or membranes within the body. Acharya Sushruta introduced the term "Kala" to describe the sheaths or membranes that enclose internal organs. These membranes separate the *Dhatu* from the *Ashayaa* (Organ Cavity). There are seven types of *Kala* in the body: *Mamsadhara*, *Raktadhara*, *Medodhara*, *Shleshmadhara*, *Purishdhara*, *Pittadhara*, and *Shukradhara*. To explore this concept, we have reviewed Ayurvedic texts, related literature, and modern anatomy sources.

Keywords: *Kala Sharir*, Layers of the body

INTRODUCTION

Kala Sharir is a key concept in Ayurvedic Sharir Rachna Vijnyana, primarily concerned with the layers and membranes that cover various organs and tissues of the body. In Ayurveda, the term "Kala" has multiple meanings, including a unit of time and a membrane, but anatomically it refers to membranous structures. This unique concept was introduced by Acharya Sushruta in the "*Garbhavyakarana Sharir Adhyaya*." Acharya Sushrut described *Kala* as the separator between *Dhatu* (tissues) and its *Ashaya* (organ or cavity), where *Ashaya* refers to the cavity that contains the *Dhatu*s. According to *Shareera Rachana* (Ayurvedic anatomy), "*Kala*" denotes the membrane that separates a *Dhatu* from its *Ashaya*. Through the action of *Dehoshma* (body heat), *Kleda* or *Anna Kleda* (moisture or nutrients) are processed (*Paaka*) to generate this membrane.





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The body's natural heat causes the *Kleda*, which is located between the *Dhatu* (tissue) and its *Ashaya* (organ cavity), to change during fetal development. *Kala* (membranous structures) are created as a result of this process. According to Acharya, the structure of *Kala* (*Kala Swaroop*) consists of body parts that are smeared with *Kapha*, covered by *Snayus* (ligaments or tendons), and encompassed by *Jarayu* (membrane or covering). *Kala* is associated with mucous membranes and epithelium in contemporary research. *Snayu* and *Shleshma* are vital parts of *Kala*, which is a membrane that secretes mucus and is shielded by *Snayus*. In the body, *Kala* can be classified into seven different types: *Mamsadhara Kala*, *Raktadhara Kala*, *Medodhara Kala*, *Shleshmadhara Kala*, *Purishadhara Kala*, *Pittadhara Kala*, and *Shukradhara Kala*. In his commentary on the Sushruta Samhita, Dalhana says that *Dhatu* refers to the seven structures that support (*Dharana*) the body. But when talking about *Kala*, Acharya stresses that in addition to the *Sapta Dhatus*, the *Tridosha* and *Trimala* also need to be taken into account because, in a balanced condition, they help support the body. *Ashaya* is sometimes referred to as the *Avasthana Pradesha*, or the area that supports the *Dhatus*. According to Astanga Samgraha, after the formation of the *Dhatus*, the remaining minute portion of *Rasa* (nutrient fluid) undergoes *Paaka* (processing) to form *Kala*. The *Dhatus*, including *RaktaDhatu*, and the *Ashaya* (the channels or *Srotas* through which they circulate) are essential elements, as Indu's commentary makes clear. *Kala* is situated precisely in the middle of *Dhatu* and *Ashaya*. The *Swaroopa* of a structure helps in its identification, and classical texts often use similes to provide a clearer understanding. *Kala* is explained in a similar way. All Acharyas described *Kala* as resembling the annual rings of a tree. Just as a tree forms a new layer of wood each year, increasing its bulk, the rings make this growth visible through distinct separations. Similarly, *Kala* provides clear demarcations in the body, though it is not solid like tree rings. Instead, it is composed of *Snaayu*, *Jarayu*, or *Kapha/Sleshma*, giving it a soft, flexible structure.

Aim And Objective

- Aim of this study is to determine the applied aspect of *Kala*.
- Objectives of this study are to compare the anatomical structure of *Kala* with the respective membrane in modern anatomy.

MATERIALS AND METHODS

From various classical texts Bruhatrayi like Charaka Samhita, Sushruta Samhita, Ashtanga Samgraha, Ashtanga Hrudaya and Laghutrayi like Madhav Nidan, Sharangadhara Samhita etc and evidence based resources as scientific journals, books and data based information from various texts.

Review of Literature***Kala Sharir***

Definition :

कलाः खल्वपि सप्त भवन्ति धात्वाशयान्तरमर्यादाः ॥Sush. Sharir 4/5

There are seven *Kala*, which are membranes or sheaths that separate *Dhatu* and *Ashaya*. While *Dhatu* represents the corresponding organ, *Ashaya* might be associated with the empty space inside the organ. Therefore, we may say that it is a differentiating membrane that observes the organ's physical form.

Formation and structure of *Kala* :

धात्वाशयान्तरक्लेदो विपक्वः स्वंस्वमूष्मणा |

श्लेष्मस्नाय्वपराच्छन्नः कलाख्यः काष्ठसारवत् |

A.Hru. Sharir 3/9

By its own heat, the liquid portion that exists between *Dhatu* and *Ashaya* transforms into *Kala*. We may conclude from examining *Kala*'s definition and construction that it is more than just a physical entity; rather, it serves as a functional and physical component in the creation and distribution of the corresponding *Dhatu*. *Mamsadhara-Kala*, *Raktadhara-Kala*, *Medodhara-Kala*, *Sleshmadhara-Kala*, *Pureeshadhara-Kala*, *Pittadhara-Kala*, and *Shukradhara-Kala* are the seven varieties of *Kala*. Dalhana makes it clear that these *Kala* are named and arranged according to their function in





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Dharana, not *Poshana*. According to Acharyas, when the notion of *Kala* is understood from the outside in, there is an oozing of *Dhatu* (tissues) when cutting through *Mamsaadi* (muscular tissue). Acharya starts with *Maamsadhara Kala*, however *Rasa* and *Rakta* should be taken into consideration first in accordance with the *Dhatu* sequence. This is because Acharya introduces *Kala* after talking about the skin (*Twak*) in his description of the body's layers. The first *Kala*, *Maamsadhara Kala*, which is in charge of the *Dharana* (support) of *Mamsa* (muscle tissue), comes after the seventh layer of *Twak*, *Mamsadhara Twak*.

Mamsadhara Kala

तासां प्रथमा मांसधरा, यस्यां मांसे सिरास्नायुधमनीस्रोतसां प्रताना भवन्ति || (Su.Sha 4/8)

Acharya Sushruta among the seven *Kalas*; *Mamsa Dhara Kalas* explained first. *Snayu* (tendon), *Sira* (veins), *Dhamani* (arteries), and *Srotas* (cavity) make up *Mamsadhara Kala*'s network. In terms of anatomy, it can be associated with the intermuscular septa or deep fascia that divide the muscle from the underlying structure. Just as lotus stems and stalks develop everywhere in muddy water on the ground, so do blood vessels and other structures in muscles. Why is *Rakta* included before *Mamsa* in the list of *Dhatu*s? The *Raktadhara* is mentioned after *Mamsadhara Kala*. There is no anomaly because this order relates to nourishment rather than support; in this case, it is about supporting *Kala*.

Raktadhara Kala

द्वितीया रक्तधरा मांसस्याभ्यन्तरतः, तस्यां शोणितं विशेषतश्च सिरासु यकृत्स्लीहनोश्च भवति || (Su.Sha 4/10)

Raktadhara Kala is the second *Kala* that Acharya Sushruta has explained. *Raktadhara Kala* is a part of *Mamsadhara Kala*, as was previously stated. Despite being embedded in the *Mamsadhara Kala*, it is especially present in the liver, spleen, and blood vessels. Similar to how latex emerges from a tree when it is cut, blood will leak from the *Raktadhara Kala* if the *Mamsadhara Kala* embedded in a muscle is cut. The *Raktadhara Kala* can be compared to the tunica externa and tunica media, which are the innermost layers of the arteries that line the lumen of the artery. The liver plays a vital part in the circulation of the fetus during embryonic life and aids in the development of blood. Spleen act on old RBC cells to get recycled and platelet and WBC get stored in to the spleen.

Medodhara Kala

तृतीया मेदोधरा, मेदो हि सर्वभूतानामुदरस्थमण्वस्थिषु च, महत्सु च मज्जा भवति || (Su. Sha. 4/12.)

The third *Kala* in the body, *Medodhara*, is found in the small and large bones as well as the abdomen. *Meda* is a type of adipose tissue that is found in the belly. Although it is found all over the body, it might collect mainly in the abdomen. The greater and lesser omentum, which cover the large intestine (transverse colon), are anatomically comparable to *MedodharaKala*. Anatomically speaking, the existence of *Medodhara Kala* in the bone can be correlated with bone marrow. In this instance, Acharya Sushruta stated that *Medodhara Kala* inhabits long bones as *Majja* and small bones as *Sarakta Meda*.

Shleshmadhara Kala

चतुर्थी श्लेष्मधरा सर्वसन्धिषु प्राणभूतां भवति ||

स्नेहाभ्यक्ते यथा ह्यक्षे चक्रं साधु प्रवर्तते ।

सन्धयः साधु वर्तन्ते संश्लिष्टाः श्लेष्मणा तथा || (Su.Sha. 4/16.)

This is *Kala* 4th. All living things' joints contain *Shleshmadhara Kala*, according to Acharya Sushruta. *Shleshma* in the joint facilitates free movement, much as enough lubrication at the wheels' frictional area contributes to smooth and high-quality movement. Additionally, it aids the joint in overcoming the tension and shock of frequent motion. For all of the joints in the body to operate smoothly, *Sheshmadhara Kala* is therefore crucial. In terms of anatomy, it is comparable to the synovial membrane that covers the inside of joints. The *Shleshma* can be correlated with the synovial fluid released by the synovial membrane.

Purishdhara Kala

पञ्चमी पुरीषधरा नाम; याऽन्तःकोष्ठे मलमभिविभजते पक्वाशयस्था ||





यकृत्समन्तात् कोष्ठं च तथाऽन्त्राणि समाश्रिता ।

उण्डु (न्दु) कस्थं विभजते मलं मलधरा कला || (Su.Sha 4/17)

Purishdhara Kala is the fifth *Kala*. It is situated inside the *Kostha* (abdomen) in the *Pakwashaya*. In the *Kostha*, it is specifically situated at the *Yakrit* level. In *Purishvaha Srotas*, food is split in the *Sara* and *Mala Bhaga* with the use of *Purishdhara Kala*. *Maladhara Kala* is another name for it. Waste items such as urine and feces are separated by *Malam Abhivibhajate*. But it interprets it as feces, which are food excretions, and *Agni* and *Vayu* work together to separate them. As a result, *Kala* is dispersed throughout the whole gastrointestinal tract, affecting nearly every viscera; it is referred to as "being situated in intestines" due to the presence of feces. *Malam Vibhajate*: "Eliminates from bowels" by separating waste products in the form of urine and feces. . The site where digested food is separated in *Sara* and *Mala Bhaga* is called *Kala*, according to Acharya Sushruta *Purishdhara*. In modern science, this location can be equated with the big intestine. According to Acharya Sushruta, as it is close to the *Yakruta*, it may be the hepatic flexure. *Purishdhara Kala* can be correlated with the mucosal and submucosal layers of the large intestine's innermost layer.

Pittadhara Kala

षष्ठी पित्तधराः अशितं खादितं पीतं लीढं कोष्ठगतं नृणाम् । तन्जीर्यति यथा लं शोषितं पित्ततेजसा || (Su.Sha 4/19)

Pittadhara Kala is the sixth *Kala*. It takes in and holds onto the partially digested meal. It breaks down all four types of food: *Lehya* (licked), *Peeta* (drinkable), *Khadita* (swallowed), and *Ashita* (chewable). It contains the digestive fire, or *Agni*, which aids in the individual's food digestion. Here, *Agni* plays a key role in food absorption and digestion. The term "*Grahni*" is typically used to refer to the duodenum or the first segment of the small intestine. It is where partially digested food is received from the stomach, held for a while, and then broken down. Therefore, the digestive enzymes that aid in food digestion may be secreted by the duodenum and its inner layer.

Shukradhara Kala

सप्तमी शुक्रधरा. या सर्वप्राणिनां सर्वशरी यापिनी ||

यथा पयसि सर्पिस्तु गूढश्चेक्षौ रसो यथा । शरीरेषु तथा शुक्रं नृणां विद्याद्विषग्वरः || (Su.Sha. 4/21.)

Shukradhara Kala is the seventh and final *kala*. It can be found all over the body. Similar to how the presence of ghee in milk is invisible to the human sight, the presence of sugar in sugarcane is also invisible to the naked eye, as is the presence of *Shukradhara Kala*. Consider *Shukra* to be semen. Since semen is created by the testes, it is not advisable to claim that it is produced throughout the body. Ayurveda likewise makes this claim while describing the *Shukravaha Srotas*. Another question that comes up in this situation is whether or not females have *Shukradhara Kala* if it is compared to semen. At the zygote level, we must comprehend the idea of *Shukradhara Kala*. Since the sperm and ovum make up the entire body, it is generally acceptable for these two cells to produce every portion of the body. We can therefore defend the idea of *Shukradhara Kala* as presented by Acharya Sushruta.

DISCUSSION

Kalas are the body parts that are coated in *Snayus*, encased in *Jarayu*, and smeared in *Kapha*. According to contemporary science, it is related to the epithelium and mucous membranes. The mucous membranes of the hollow organs can be thought of as *Kala* divides the organ's lumen or hollow from its lining tissue. It is a structure that stands in between the *Ashaya* and the *Dhatu*. The layers of *Kala* not only serve as anatomical boundaries but also play integral roles in various physiological processes, such as nourishment, support, lubrication, and reproduction. The correlation of these *Kalas* with modern anatomical structures enhances our understanding of their significance and functions in both Ayurvedic and contemporary medical contexts. Through this discussion, it is evident that the concept of *Kala* is multifaceted, interconnecting various anatomical structures and functions, highlighting the complexity of the human body as perceived in Ayurveda. This holistic perspective allows for a deeper appreciation of the interplay between the body's tissues and their roles in maintaining health and well-being.





CONCLUSION

The restricting membrane that separates a *Dhatu* from its *Ashaya* is called *Kala*. Here, "*Dhatu*" refers to the seven main Dhatus (*Rasadi Sapta Dhatu*), *Trimalas* (three excreta), and *Tridoshas* that, when in a healthy state, are in charge of preserving the integrity of the body. The term "*Ashaya*" refers to the particular hollow or space where these *Dhatus* are found. Under the effect of (internal heat), *Kala* is created by the *Paaka* of *Kledaamsa*, which is located between the *Dhatu* and *Ashaya*. It is like the annual rings of a tree, like the *Saara* of *Kashta*. *Kala*'s structure can be compared to that of *Snaayu* (ligaments), *Jarayu* (connective tissue), or *Sleshma* (mucus). Its location and appearance indicate that the body's membranes are slimy, thin, and translucent, or fibrous.

The following are the likely associated structures for each *Kala*:

- *MamsaDhara Kala* : Deep fascia alterations are linked to *Maamsadhara Kala*.
- *Raktadhara Kala*: Similar to the liver and spleen's architecture, as well as the endothelium lining of blood vessels.
- *Medodhara Kala*: Associated with the endosteum of bones, peritoneal folds, and dura mater.
- *Sleshmadhara Kala*: This is the synovial membrane that lines the fibrous capsules of the flexor sheath, bursa, omental bursa, and synovial joints.
- *Pureeshadhara Kala*: Similar to the epithelial lining of the cecum, ascending colon, terminal portion of the small intestine, and a portion of the transverse colon.
- *Pittadhara Kala*: Associated with the duodenum's epithelial layer and some jejunal segments. *Shukradhara Kala*: *Sarva Daihika Shukra* is difficult to find a structural correlation for. On the other hand, *Shukradhara Kala*, which is related with *Mootra Maarga*, might be likened to the lining of the male urethra.

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A Review Focusing on Recent Advancements in LCMS Instrumentation, Software and Methodologies for Enhancing Method Development Efficiency, Sensitivity and Selectivity

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ABSTRACT

Liquid chromatography-mass spectrometry (LCMS) is a key method in analytical chemistry. Its ability to combine high-resolution separation with precise mass detection has changed industries like pharmaceuticals, environmental monitoring, and clinical diagnostics. In this review, we look at current advances in LCMS, such as instrumentation, software tools, and method development approaches. Our focus is on improving efficiency, sensitivity, and selectivity, allowing researchers to fully realize the potential of LCMS. Due to its exceptional sensitivity and selectivity in detecting and quantifying a broad variety of compounds, liquid chromatography-mass spectrometry (LCMS) has emerged as an essential analytical chemistry instrument. The development of LCMS methods is still difficult, especially when trying to achieve the best possible levels of sensitivity, selectivity, and efficiency. Aiming to solve these



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difficulties, notable developments in LCMS software, instrumentation, and techniques have been achieved recently. With an emphasis on increasing method development efficiency, sensitivity, and selectivity, this review offers a thorough summary of the most recent advancements in LCMS technology and methodology. The article discusses significant developments in LCMS apparatus, software tools, and method development methodologies, as well as how they affect analytical chemistry research and applications.

Keywords: Liquid Chromatography-Mass Spectrometry (LCMS), Analytical chemistry, LCMS technology and methodology, software tools.

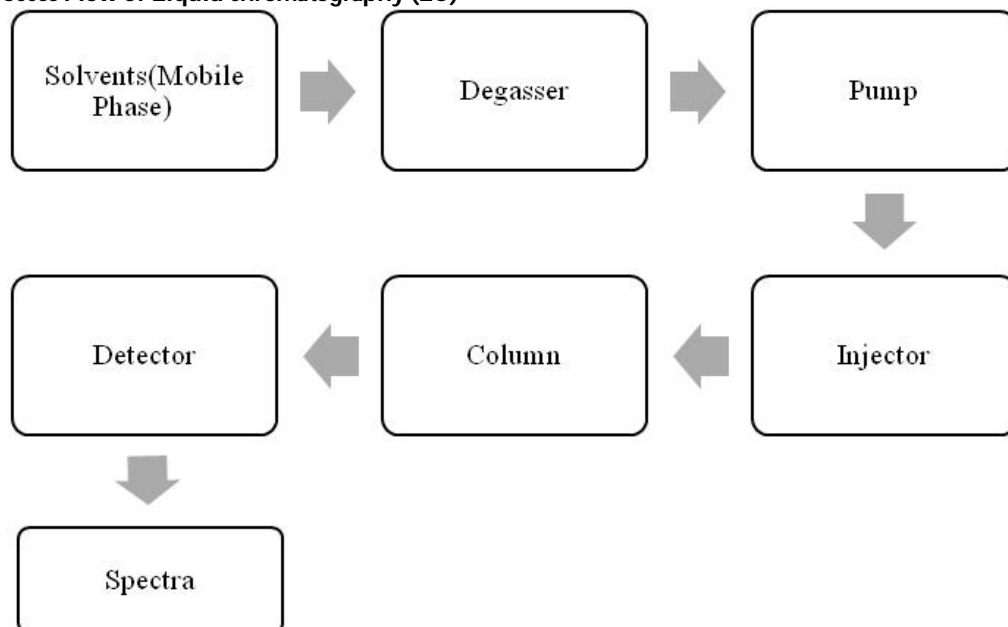
INTRODUCTION

The objective of Liquid chromatography (LC) coupled with mass spectrometry (MS) has become an essential analytical tool. However, despite its widespread use, method development remains a challenging task. The interplay of numerous parameters, matrix effects, and the need for sensitivity and selectivity necessitates innovative approaches. In this article, we delve into the latest developments that address these challenges. A effective analytical method for the detection, identification, and quantification of a broad variety of chemicals in complicated matrices is liquid chromatography-mass spectrometry (LCMS). The separation powers of liquid chromatography and the sensitive and selective detection powers of mass spectrometry are combined in LCMS, which makes it an effective tool for a variety of industries, including environmental analysis, metabolomics, proteomics, medicines, and forensics. However, the creation of reliable and effective techniques for sample preparation, chromatographic separation, and mass spectrometric detection is crucial to the effective use of LCMS. Significant improvements in LCMS hardware, software, and methodology have been created recently with the goal of addressing method development issues and enhancing the effectiveness, sensitivity, and selectivity of LCMS analysis.

Liquid Chromatography

1. Liquid chromatography is a separation process used to isolate the individual components of a mixture. This process involves the mass transfer between a sample and a polar mobile phase as well as non-polar stationary phase.
 2. LC separates the molecules in a liquid mobile phase using solid stationary phase. This separation occurs based on the interaction of the sample with the mobile and stationary phases. It can be used for the analytical or preparative application.
 3. This technology requires sophisticated instrument operating at high pressures, hence using abbreviation of LC and HPLC interchangeable.
 4. The reasons for the popularity the method are its sensitivity, its ready adaptability to accurate quantitative determination, its ease of automation, its suitability for separating non-volatile species or thermally fragile once its wide spread applicability to substances that are important to industry and many fields of science .[1]
- The columns were packed with 50 to 500 cm length of solid particles coated with an adsorbed liquid that formed the stationary phase.
- To ensure reasonable flow rates through this type of stationary phase, the particle size of the solid kept larger than 150 to 200 μm .



**Process Flow of Liquid chromatography (LC)****Mass Spectrometry**

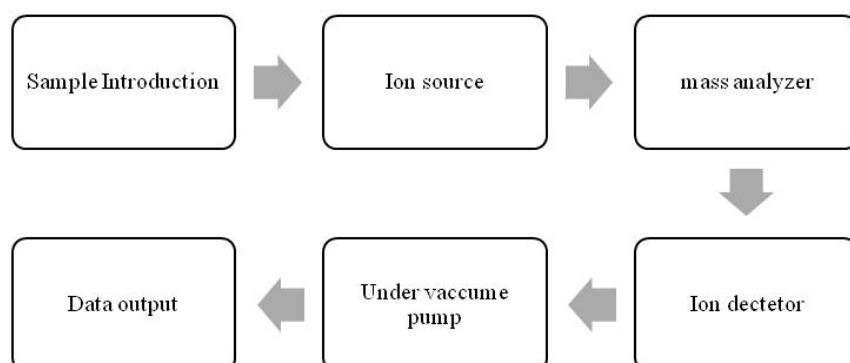
A mass spectrometer is an instrument that produces ions and separates them according to their mass to charge ration (m/z).

Mass spectrometric analysis involves the following steps:

- Atomization
- Conversion of a substances fraction of the atoms formed in step1 to a stream of ions.
- Separating the ions formed in step 2 on the basis of their mass to charge ratio [m/z].

M =mass of the number of ion in atomic mass unit.

Z =number of fundamental charges. [2]

Process Flow of Mass Spectroscopy (MS)

**Sridevi Ranjitha Karanam et al.,****Liquid Chromatography- Mass Spectrometry**

LC-MS is an analytical technique that couples high resolution chromatographic separation with sensitive and specific mass spectrum detection.

- Combination of LC-MS is an important development in the history of chromatography. Mass spectroscopy in LC-MS helps to determine the elemental composition and structural elucidation of a sample.
- It is powerful technique used for many applications which has very high sensitivity and selectivity. It is commonly used in the pharmacokinetic studies of pharmaceuticals and it is the most frequently in field of bioanalysis. LC-MS also play a role in pharmacognosy especially in the field of molecular pharmacognosy when it comes to the ingredients in the different aspects of phenotypic cloning. [3]

Principle Involved In LC-MS

- Typical LC-MS system is the combination of HPLC with MS using Interface (Ionisation source). The sample is separated by LC and the separated sample species are sprayed into atmospheric pressure ion source, where they are converted into ions in the gas phase.
- The mass analyser is then used to sort ions according to their mass to charge ratio and detector counts the ions emerging from the mass analyser and may also amplify the signal generated from each ion.
- As a result mass spectrum (a plot of the ion signal as a function of mass to charge ratio) is created, which is used to determine the elemental nature of a sample, the masses of the particle and also molecules, and to elucidate the chemical structures of molecules.
- Two key components in this process are the ion source, which generates the ion and mass analyzer, which sorts the ions. Several different types of ions sources are commonly used for LC/MS. [3]

Advancements in LCMS Software

In parallel with advancements in instrumentation, there have been notable developments in LCMS software tools for data acquisition, processing, and analysis. Modern LCMS software platforms offer user-friendly interfaces, advanced data processing algorithms, and integrated workflows for method development, optimization, and validation. These software tools facilitate automated peak detection, deconvolution, quantification, and identification of analytes, thereby streamlining method development workflows and reducing analysis time. Furthermore, the integration of machine learning algorithms and artificial intelligence techniques into LCMS software enables predictive modeling, retention time prediction, and automated peak assignment, enhancing method robustness and reproducibility.

1. Two-Dimensional LC (2D-LC): The evolution of 2D-LC methods has significantly expanded peak capacities and improved mass spectrometry utilization. These methods allow faster analysis of complex samples compared to traditional one-dimensional (1D)-LC approaches [4].
2. In-Line Reactions: LCMS now enables in-line reactions, enhancing the scope of applications. Researchers can perform derivatization, ionization, and other reactions directly within the LC system, leading to improved sensitivity and selectivity.
3. High-Resolution Mass Analyzers: Advances in mass analyzers, such as quadrupole-orbitrap hybrids and time-of-flight (TOF) instruments, provide superior resolution and accurate mass measurements. These innovations enhance compound identification and quantification.

Method Development Strategies

Effective method development is essential for achieving optimal performance in LCMS analyses. Recent advancements in method development strategies have focused on improving chromatographic resolution, selectivity, and sensitivity while minimizing analysis time and solvent consumption. Strategies such as gradient optimization, column selection, mobile phase modifiers, and sample preconcentration techniques have been widely explored to enhance chromatographic performance and analyte detection. Moreover, the application of orthogonal chromatographic techniques (e.g., two-dimensional LC) and multidimensional separations has enabled the comprehensive analysis of complex samples with improved resolution and peak capacity.



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The unit study method is one that is regularly created, enhanced, verified, investigated, and used in a collaborative manner. Separations between activities are mostly required while developing broad approaches for LC-MS technique development. Most of the time, desirable separations can be obtained with just a few experiments.

In other situations, a significant amount of experimentation might also be made public.

The procedure for developing techniques:

- Gather the drug's chemical characteristics from published sources.
- Verify the profile of soluble substances.
- MS optimisation and scanning.
- Choice of mobile phase selection.
- Selection and optimisation of the extraction method.
- Selecting the activity technique (based on chemical retention and solubility studies)

Software Tools for Method Development Efficiency

1. Chemometrics and Machine Learning: Researchers worldwide are designing strategies to simplify method development using software. Chemometrics and machine learning allow simultaneous optimization of multiple parameters, streamlining LCMS workflows [5].
2. Closed-Loop Optimization: Computer-aided workflows optimize kinetic and thermodynamic parameters in LC. Closed-loop approaches continuously adjust method conditions based on real-time data, reducing manual intervention.

Methodologies for Enhanced Efficiency

1. **Quality by Design (QbD):** QbD principles guide LCMS method development by emphasizing risk assessment, design of experiments (DoE), and systematic optimization. This approach ensures robust and efficient methods [6].
2. **Column Selection and Stationary Phases:** Advances in column technology, including superficially porous particles (SPPs) and monolithic columns, enhance separation efficiency and speed.
3. **Mobile Phase Optimization:** Rational selection of mobile phases, additives, and gradients improves sensitivity and selectivity. Techniques like gradient scouting and solvent strength optimization play a crucial role.

Applications in Pharmaceutical Analysis:[7-8]

LC-MS is a comprehensive solution that addresses a wide range of issues in pharmaceutical research and development, not merely a tool. It offers scientists a strong, dependable, and adaptable platform to gather vital data at every phase of the drug development process. The pharmaceutical business relies heavily on Liquid Chromatography-Mass Spectrometry (LC/MS) as a vital instrument for a variety of tasks, including medication discovery and market support. It is essential to many phases of research since it offers information on drug compound discovery, chemical development, stability testing, and other topics. For example, LC/MS is used for structural verification during chemical development and for quick target compound monitoring during the discovery stage. As a crucial component of pharmaceutical standards and impurity profiling, it is also necessary for monitoring impurity profiles.

Current Developments in LC-MS:[8]

Recent years have seen tremendous developments in the strong analytical technology known as liquid chromatography-mass spectrometry, or LC-MS. This technology is essential for many industries, including medicine.

Hardware Upgrades

- Improved ionisation methods
- More perceptive sensors
- Enhanced effectiveness of the system

The quality of pharmaceutical products has increased due to the ability to detect contaminants at even lower concentrations thanks to advancements in hardware.



**Ionization's Importance in LC-MS**

Conventional Techniques for Ionisation

An LC-MS system's ionisation source is its essential component. The magic starts there, converting substances into ions that can be separated and examined.

- Electrospray Ionisation (ESI): This approach is dependable and versatile, similar to a Swiss Army knife of ionisation techniques. It is especially helpful for studying polar, nonvolatile, and thermally labile substances.
- Atmospheric Pressure Chemical Ionisation (APCI): APCI is a powerful, noiseless method that completes tasks with minimal disturbance. For less polar or nonpolar substances with smaller molecular weights, this is the preferred technique.
- Although not as often utilised as ESI and APCI, atmospheric pressure photo-ionization (APPI) has its uses. Its reduced sensitivity in comparison to other approaches is its main drawback.

The Latest Developments in Ionisation Methods

Ionisation techniques are no different—innovation never ends. The following are a few of the newest technologies available:

- UniSpray: Waters Corporation introduced UniSpray, which takes advantage of the Coanda and vortex effects to facilitate droplet dissolution and break-up. It resembles ESI on an elevated level.
- The Electrospray Ionisation intake (ESII) is a novel technique that involves applying a voltage to a metal union that joins a section of fused silica tubing placed into a mass spectrometer's heated intake tube to tubing from a solvent supply system. It's as inventive and effective as the Tesla of ionisation techniques.

CONCLUSION

Although LC-MS technology has advanced significantly, its path is far from done. With ongoing developments in hardware capabilities, data analysis software, and ionisation methods, LC-MS is poised to further transform the pharmaceutical sector. It's more than simply a tool; it's a spark that propels advancement in the search for safer and more potent medications.

Looking it up, the efficiency, sensitivity, and selectivity of method development have been greatly improved by recent developments in LCMS hardware, software, and techniques. Advanced mass spectrometry technology, powerful software tools, and creative approach development tactics have come together to create a platform for more robust and dependable mass spectrometry analysis in a variety of applications. To further develop LCMS technology and methodology, solve current issues, and open up new avenues for analytical chemistry research and applications, more research is necessary.

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Table.1: Applications in Pharmaceutical Analysis

AREA	APPLICATIONS
Finding of a Potential Drug	<ul style="list-style-type: none"> • Quick LC/MS for tracking intended medication candidates. • High-precision mass spectrometry to demonstrate structural integrity. • Pharmacokinetic and metabolic studies conducted in vitro.
Development of Chemical Drugs and Scale-Up	<ul style="list-style-type: none"> • Final drug candidates, intermediates, and starting materials structural confirmation • Impurity profile monitoring from batch to batch • Drug substance/synthetic impurity qualification and characterization as reference standards
Testing for Stability	<ul style="list-style-type: none"> • Tracking changes in the purity and impurity profiles • Examining how well medication components, formulation excipients, and packaging materials work together • Degradation and intrinsic stability analysis • Chromatographic peak purity analysis • Impurity profile establishment in a stressful environment
Drug Metabolism, Pharmacokinetic, and Toxicological Studies	<ul style="list-style-type: none"> • Medication metabolite identification in physiological settings • Measuring the amount of medication and its metabolites in the biological matrix
Product assistance following market/sale	<ul style="list-style-type: none"> • Impurity profiles are monitored during the investigation. • Impurity profiles on drug goods and substances under long-term storage circumstances are continuously examined. • Examining samples of customer complaints • Looking into products that are counterfeit drugs





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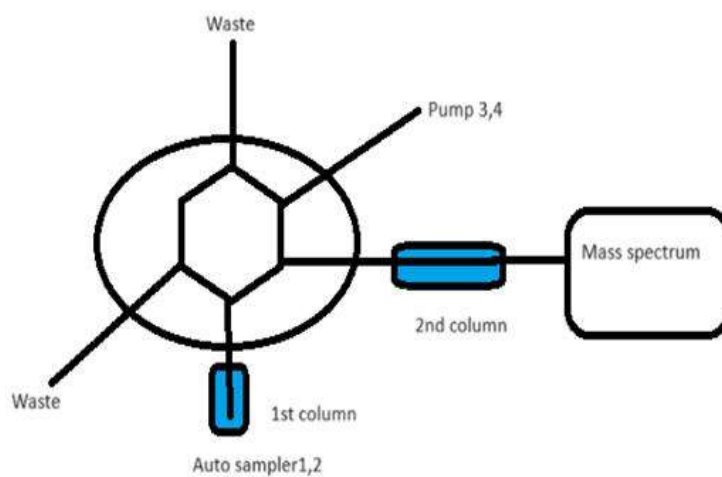


Figure.1: 2D LC-MS Spectroscopy





The Impact of Gender in Influencer Marketing: A Study of Brand Awareness in the Fashion Sector

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ABSTRACT

This research critically investigates the differential effects of male and female social media influencers on brand awareness within the fashion sector, with a focus on gender as a moderating element. The study, utilizing the theoretical frameworks of celebrity endorsement and consumer behavior, reveals notable gender-based differences in the impact of critical traits such as expertise, trustworthiness, beauty, and information quality on brand awareness. The results indicate that trustworthiness is a more significant component in augmenting brand awareness for male influencers, while attractiveness is essential for female influencers. These findings highlight the imperative for firms to implement gender-targeted influencer marketing tactics to enhance customer engagement and brand visibility. This study enhances comprehension of influencer marketing dynamics in the fashion industry by providing detailed insights into the impact of influencer gender, having practical implications for brand management.

Keywords: Social media influencer, female influencer, male influencer, brand awareness, fashion industry, moderation



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INTRODUCTION

Influencer marketing has emerged as a potent weapon in the fashion industry as a result of the revolution in the way brands interact with consumers that has been facilitated by the proliferation of social media (Sharabati *et al.*, 2024; Rutter *et al.*, 2021). Influencers, who frequently have substantial followings on platforms like Twitter and Instagram, collaborate with brands to increase visibility and awareness (Lou & Yuan, 2019). The gender dynamics involved in influencer marketing have not been fully understood, despite the extensive exploration of its effectiveness. In the context of fashion, where visual aesthetics and personal identity play crucial roles, the gender of the influencer may wield significant influence over brand perception and engagement (Andika *et al.*, 2024; Gupta *et al.*, 2024). Research has demonstrated variations in consumer behavior and response based on the gender of both the influencer and the audience (Djafarova & Rushworth, 2017). However, comprehensive studies comparing the differential impact of male and female influencers within the fashion industry are lacking. Gender as a moderating variable may interact with other factors, such as content style, audience, demographics, and cultural context, to produce nuanced effects on brand awareness (Khamis *et al.*, 2017). Understanding these dynamics is essential for fashion brands aiming to optimize their influencer marketing strategies. This study aims to explore the differential impact of male and female influencers on brand awareness in the fashion industry, employing a moderation approach. Specifically, it will investigate how gender interacts with various factors to influence consumer perception, engagement, and ultimately, brand awareness.

Review of Literature

Fashion Influencers

Fashion influencers (FIs) are individuals with a substantial following across many social media channels. They actively produce and distribute fashion-related content, so exerting considerable influence on the views and purchase choices of their followers. Chetioui *et al.* (2020). The research by Lee and Youn (2021) investigated the impact of fashion influencers on brand awareness and memory development. The study's findings highlighted that fashion influencers may enhance the recognition and recall of fashion brands through the creation of relevant and engaging content. The study emphasized the importance of employing influencer collaboration as a tactic to increase brand visibility.

Gender Differences in Influencer Impact

Several studies have investigated the influence of gender in the impact of influencers on brand awareness. Al-Shehri M. (2021) found that female influencers were more effective in stimulating purchase intention among female consumers, while male influencers had a stronger impact on male consumers. This suggests that gender alignment between influencers and target consumers can enhance brand awareness. Moreover, research by La Tupikovskaja-Omovie *et al.* (2020) using eye-tracking techniques revealed that male and female consumers focused their attention differently when exposed to fashion advertising featuring male or female influencers. This indicates that the gender of the influencer can significantly influence consumers' cognitive and visual processing of brand information, thereby affecting brand awareness. Consumer attitudes and perceptions toward celeb endorsements are often molded by gender stereotypes. (Kanwal *et al.*, 2022) suggest that men are generally more inclined to engage with the web for functional tasks and entertainment, whereas women are more likely to use it for shopping purposes. Additionally, their study found that men tend to have more favorable attitudes toward online advertising than women. The effectiveness of male celebrity endorsements has been particularly evident in promoting products traditionally associated with masculinity, such as sports gear or men's grooming products. Erdogan *et al.*, (2001) found that male celebrities are often viewed as credible and aspirational figures by both male and female consumers, leading to positive evaluations of the brand and increased purchase intentions. Similarly, female celebrity endorsements have been shown to significantly influence consumer attitudes, particularly for products associated with femininity, such as cosmetics or fashion items. Macheka *et al.* (2024), highlighted the unique effectiveness of female endorsers in shaping consumer perceptions of beauty, style, and personal identity, particularly among female audiences. As a result, their endorsements tend to have a positive effect on brand awareness and consumer behavior.



**Expertise**

Social media influencers with competence have proven superior leadership of opinion compared to those without expertise (Nadanyiova *et al.*, 2020). According to McQuarie *et al.* (2012), Expertise refers to an individual's superior knowledge and experience in making informed product decisions or choices compared to others. When an influencer demonstrates professional understanding regarding the product they are advocating, the social media audience will perceive this as a demonstration of refined taste as opposed to a simple personal remark or opinion (Ki & Kim, 2019). The hypothesis based on the preceding studies is as follows: H1: Expertise of the influencer has a significant impact on brand awareness.

Trust worthiness

Trustworthiness, defined as the perceived honesty and reliability of a communicator (Erdogan, 1999), is a key factor contributing to the credibility of social media influencers (SMIs) (Balaban *et al.*, 2019). According to Erdem *et al.* (2006), consumers tend to associate trustworthy brands with higher product or service quality, which in turn fosters positive evaluations of the brand. Similarly, research by Bazaarvoice (2018) highlights that consumers place greater value on influencers who are open about their relationships with brands, particularly when they disclose sponsored content. Such transparency enhances the influencer's credibility and trustworthiness. Choi and Rifon (2012) argue that when influencers are perceived as trustworthy, consumers are more likely to extend that trust to the brands they promote. Manzoor *et al.* (2023) also found that an influencer's perceived trustworthiness has a significant impact on consumers' intentions to make a purchase. Matin *et al.* (2022) further note that brand-specific disclosures, such as those indicating paid partnerships, improve how trustworthy an influencer appears to the audience. This enhanced trustworthiness acts as a mediator, influencing consumer behavior, including their intent to purchase and their overall perception of the influencer. For this reason, the hypothesis made is; H2: Trustworthiness of the influencer has a significant impact on brand awareness.

Attractiveness

A person's physical beauty is related to their appearance: How pleasant or unappealing is the source? Beauty is typically characterized as "the degree to which a stimulus person's face characteristics are pleasurable to see," as stated by Patzer (1983). Dholakia and Sternthal (2007) state that if the Influencer and the brand are both appealing, it can boost the endorsement's efficacy and positively affect brand awareness. Assessing how well the Influencer's charisma meshes with the tastes of the intended consumers is crucial. According to AlFarraj *et al.* (2021) and Chekima *et al.* (2020), influencer credibility is based on three main factors: expertise, honesty, and beauty. Businesses can interact with potential clients using influencers' attractiveness as a point of reference (Chekima *et al.*, 2020). The physical attributes, adoration, charisma, and athletic prowess of an influencer are all factors that contribute to their overall appeal (AlFarraj *et al.*, 2021; Torres *et al.*, 2019). Glucksman (2017) argues that in order to develop consumer-brand relationships, social media influencer marketing is essential. Why? Because following the lead of an idolized influencer is associated with increased brand loyalty among consumers (Grohmann, *et al.*, 2013). By enticing social media influencers to participate in social media brand campaigns, brands may boost satisfaction, trust, loyalty, and image with potential customers through direct interactions (Wiedmann & von Metenheim, 2020 ; Glucksman, 2017). The following theory is put out in light of the above reasons: H3: Attractiveness of the influencer has a significant impact on brand awareness.

Information Quality

Information quality refers to the accuracy, completeness, relevance, and reliability of the information provided to consumers. Research by Bhattacharjee and Sanford (2006) suggests that higher information quality leads to higher perceived credibility. When consumers perceive information about a brand as accurate, reliable, and relevant, they are more likely to develop a positive perception of the brand, leading to increased brand awareness. Information quality also influences consumer decision-making processes. Research by Flavián *et al.* (2006) indicates that consumers rely on high-quality information to gather knowledge and make informed decisions. When consumers are exposed to comprehensive and accurate information about a brand, they are more likely to consider the brand during their decision-making process, thus increasing brand awareness. Therefore the following hypothesis is proposed H4:



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Information Quality of the influencer has a significant impact on brand awareness. Moreover, the gender of influencers, in particular, may present an intriguing moderation effect in these relationships. While studies have explored the influence of gender in traditional advertising (Eisend, 2010), the specific interplay between gender and influencer attributes within social media contexts remains an uncharted area. This study aims to explore this critical intersection, examining how the gender of social media influencers moderates the relationships between Expertise, Trustworthiness, Attractiveness, Information Quality, and Brand Awareness. Thus, the proposed hypothesis is H5: The gender of social media influencers moderates the relationship between Expertise, Trustworthiness, Attractiveness, Information Quality, and Brand Awareness, such that these attributes affect Brand Awareness differently for male and female influencers.

RESEARCH METHODOLOGY

To address the goal of this study, a quantitative research methodology was utilised. For this study, both primary and secondary data were used to analyse the differential impact of male and female fashion industry influencers on Brand Awareness. The secondary data obtained from both foreign and domestic journals. The primary data were acquired using self-administered questionnaires and distributed to respondents.

Research framework

The study employs the source credibility and source attractiveness models to establish its conceptual framework in accordance with its research aims. The source credibility model, first introduced by Hovland *et al.* (1953), suggests that the credibility of a source is determined by two main factors: perceived knowledge and trustworthiness. Expanding on this framework, McGuire (1985) proposed the source attractiveness model, which emphasizes the significance of source attractiveness or likability as an extra factor in determining source trustworthiness. Ohanian (1990) elaborated on these models in relation to celebrity endorsements, highlighting that source credibility encompasses knowledge, trustworthiness, and attractiveness. In addition, another factor that influences brand awareness is the quality of information (Dao *et al.*, 2014). The impacts of social comparison, trust, tie strength, and network homophily on brand-related outcomes such as brand recognition, brand engagement, brand commitment, and membership intention are investigated in Phua *et al.*'s (2017) study. By merging them all together, the conceptual framework is constructed shown in figure 1.

Research Instrument and Pilot Study

The survey was divided into two parts. The initial half of the survey examined the socio-demographic traits of the participants and the individuals who affect them, specifically their gender. The subsequent part of the questionnaire assessed the residents' impression of the influence of social media influencers on Brand Awareness. Participants were instructed to evaluate 21 statements using a 5-point Likert scale ranging from 1 to 5, where a rating of "1" indicated "strongly disagree" and a rating of "5" indicated "strongly agree". The scale comprises two primary factors, namely Influencer Attributes and Brand Awareness. The exogenous variable Influencer Attributes comprises four first-order reflective constructs: Expertise, Trustworthiness, Attractiveness, and Information Quality. The scale used to assess source credibility, which includes expertise, trustworthiness, and attractiveness, was adapted from Ohanian (1990) and adjusted for the current study. To measure information quality, the scale developed by Cheung (2012) was employed. The variable Brand awareness is an endogenous construct of first-order reflection. To get to the meat of the study, it was lifted from Fernando's 2020 research. Ten research scholars, two academics, and six professionals from the business world tried out the tool first. In order to determine the instrument's reliability, 25 participants in the pilot research filled out the questionnaire after it had been pre-tested. Each construct's dependability was far greater than Nunnally's (1978) suggested threshold of 0.70.

Study Settings and Sampling Design

The study was conducted in the Union Territory of Kashmir, India, focusing on the picturesque Kashmir Valley. Data collection involved the distribution of 365 questionnaires among respondents in the region. The sampling method



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employed was convenience sampling, selecting participants based on accessibility and willingness to participate (Bhat et al., 2023 ; Trochim 2021). From the distributed questionnaires, 220 were deemed valid for further analysis. This subset forms the basis for exploring the relationship between social media influencer attributes and their impact on Brand Awareness.

Sample size calculation with G* Power Analysis

G* Power software was used to perform power analysis, to confirm that the sample size is adequate for multiple regression; The analysis used these settings:

Effect size, denoted as f^2 magnitude relates to a medium 0.15 effects of numerical nature The level of significance (α) is set at 0.05 It is the complement of type II error likelihood Beta (β), equals 1 and itself expressed as in numbers, power = 0.80 Count of predictors: 5.

The formula is as follows:

$N \geq (\text{Power} - \text{Alpha}) (\text{Effect Size} + \text{Number of Predictors})$ So we did a G* Power analysis for this and found out that 92 subjects to show a medium effect. As for the present sample size (i.e., 220 responses), previous studies indicated that it is sufficient to detect an effect size of medium magnitude with a high level of statistical power, based on common guidelines (Cohen, 1988; Faul et al., 2009).

DATA ANALYSIS AND RESULTS

Data screening is an essential step before proceeding to further multivariate analysis. Finding out if there is a missing value, an unengaged response, or an outlier requires the correct data screening (Gaskin, 2017). So, all the data was run through a frequency test in the Statistical Package SPSS 20.00, and there were no outliers found. This descriptive analysis provides an overview of the respondent's demographic profile, shedding light on important characteristics such as Gender, monthly income, age, social media usage etc. The results of demographic characteristics are summarized in table I. The data primarily showcases a young, educated demographic, with 72.72% being students, most aged between 18-34 years. A significant 90.90% use social media daily, with Instagram being the preferred platform for 55%. The primary fashion interest lies in clothing and apparel at 65%. Therefore, marketing efforts targeting this group would likely be most effective on Instagram, emphasizing clothing and apparel trends.

Reliability Results

Zigmond (1995) defines reliability in terms of internal consistency "which is the instrument's ability to correlate with other items on the sample scale that measure the same construct". Cronbach's alpha coefficient was used to determine the reliability of the instrument. A Cronbach's alpha of 0.70 or more (Nunnally, 1978) indicates that the measuring scale employed to quantify a construct is moderately dependable. The reliability test results are summarized in Table II below.

Measurement Model

There was a finding that the item loadings in the measurement model were higher than the permissible limit of 0.60. According to Chin (1998). We used Composite Reliability (CR) and Average Variance Extracted (AVE) to check if the components were valid and convergent. Values greater than 0.07 and 0.50, which are the recommended thresholds (Hair et al., 2006), indicate convergent validity. After that, we checked for discriminant validity. When the square root of each concept's average variance extracted (AVE) is larger than its correlation coefficient, discriminant validity is proven (Fornell & Larcker, 1981). Table V shows all of the CFA's results. According to the results of the model fit analysis, the data matches the model very well: At the 0.000 level of probability, we find the following: RMSEA=0.072, $\chi^2=382.358$, $df=178$, CFI=0.948, IFI=0.949, TLI=0.939, GFI=0.836, and AGFI = 0.805.

Tables III and IV contain a summary of the results regarding the reliability, convergent validity, and discriminant validity of the tested constructs, as well as the extensive outcomes of the Confirmatory Factor Analysis (CFA).



**Ayash Manzoor et al.,****Hypotheses Testing**

Next, we will use structural equation modeling (SEM) to assess the proposed hypotheses after confirmatory factor analysis is finished. With an χ^2 value of 382.358 and 178 degrees of freedom, the model's findings show that the data and the model are well-fit. We have a lot of faith in the fit because the likelihood level is so low at .000. A satisfactory match is indicated by the CMIN/df ratio of 2.148. All three fit indices 0.948 for the comparative fit index, 0.949 for the incremental fit index, and 0.939 for the Tucker-Lewis index point to a good match. Fit is moderate, according to the goodness-of-fit index (GFI) of 0.836 and the adjusted goodness-of-fit index (AGFI) of 0.805. With an RMSEA of 0.072, we can say that the relationship is rather well-fitted. There is a favorable correlation between influencer knowledge, trustworthiness, attractiveness, and information quality and brand awareness, according to the research. All four of these components' beta coefficients 0.195, 0.261, 0.242, and 0.175 have p-values below 0.05. These results are shown in Figure 2. Therefore, H1, H2, H3, and H4 were all supported by the investigation's findings. Table V summarizes the results of the hypothesis tests.

Moderation Results

The current study examined the moderating effects of persuasion, specifically whether male or female influencers moderate the link between influencer qualities and brand awareness. The participants were surveyed regarding their susceptibility to persuasion and were divided into two groups: male influencers (n=113) and female influencers (n=107). The initial analysis involved running the model for male influencers. The findings indicated that Influencer Trustworthiness had the greatest impact ($\beta_1 = 0.320$, $p < 0.05$), followed by Influencer Attractiveness ($\beta_2 = 0.252$, $p < 0.05$), Influencer Expertise ($\beta_3 = 0.249$, $p < 0.05$), and Influencer Information Quality ($\beta_4 = 0.208$, $p < 0.05$) (Figure 3). The results of the model for female influencers indicated that Influencer Trustworthiness had the highest impact ($\beta_1 = 0.268$, $p < 0.05$), followed by Influencer Attractiveness ($\beta_2 = 0.255$, $p < 0.05$), Influencer Expertise ($\beta_3 = 0.223$, $p < 0.05$), and Influencer Information Quality ($\beta_4 = 0.149$, $p < 0.05$) (Figure 4). The study's results indicate a significant disparity between the attractiveness of female influencers and the expertise of male influencers, as determined by testing for crucial ratio differences ($p \text{ value} < 0.05$).

DISCUSSION AND CONCLUSION

This study focuses on the distinct effects of male and female influencers on brand awareness in the fashion industry. It emphasizes four crucial factors: influencer expertise, trustworthiness, attractiveness, and information quality (Sokolova & Kefi, 2020; Lou & Yuan, 2019). The impact of male and female influencers on brand awareness varies based on gender. Sokolova and Kefi (2020) found that trustworthiness is a significant factor for male influencers. This suggests that reliable male influencers exert a stronger impact on brand awareness. Trustworthiness was the primary factor, while expertise, attractiveness, and information quality played a secondary role in contributing positively. Female influencers experienced a significant impact on brand awareness through attractiveness, while trustworthiness continued to hold its importance, highlighting its universal significance (Lou & Yuan, 2019). Djafarova & Rushworth (2017) also noted the significance of expertise and information quality, albeit with less prominence than male influencers. The results indicate that audience reactions to influencers vary depending on gender. Audiences tend to judge female influencers more on their attractiveness, while evaluating male influencers more on their expertise. De Veirman et al. (2017) highlight the importance of brands implementing gender-specific influencer strategies.

Practical Implications

Fashion brands should consider using strategies tailored to specific genders when choosing and partnering with influencers. Male influencers should prioritize demonstrating their expertise and credibility (Freberg et al., 2011). When targeting female influencers, it is important for campaigns to focus on visual appeal and aesthetics in order to leverage their attractiveness. Establishing trust is crucial for brands when partnering with influencers. Selecting influencers known for their authenticity and credibility is crucial, instead of concentrating solely on their follower count (Schouten, Janssen, & Verspaget, 2020). Furthermore, content quality is of utmost importance. Research



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suggests that male influencers are well-suited for providing in- depth product reviews and valuable insights. On the other hand, female influencers excel in creating visually appealing content and captivating narratives (Godey et al., 2016). Brands can enhance their strategies by creating an influencer matrix to assist in selecting the most suitable influencers for their campaigns. This matrix will help ensure that the chosen influencers align with the brand's specific goals, whether it is to showcase expertise through male influencers or to attract attention visually through female influencers (Jin, Muqaddam, & Ryu, 2019). Finally, it is crucial for brands to remain aware of the ever-changing trends in influencer marketing. It is important to regularly update and adapt influencer strategies in order to maintain effectiveness in this ever-changing landscape (Godey et al., 2016). Overall, gaining a thorough understanding and strategically implementing the varying effects of male and female influencers can greatly improve brand awareness campaigns within the fashion industry.

Limitations of the Study

While the study offers insightful information, it should be noted that it has significant limitations. Firstly, the findings are contingent on the characteristics and behaviours of the specific sample of participants, potentially leading to sample bias. Generalizing these findings to broader populations might not capture the full spectrum of consumer and influencer dynamics. Additionally, the study's focus on the fashion industry could limit the applicability of its conclusions to other industries, where distinct influencer dynamics might prevail. Furthermore, contextual factors such as cultural variations, regional preferences, and evolving consumer behaviors might not have been fully considered.

Future Recommendations

To advance the understanding of this field, several avenues for future research can be explored. Longitudinal studies tracking the evolving impact of male and female influencers over time could reveal dynamic trends and changes. Expanding the investigation beyond the fashion industry to compare results across different sectors would provide a more comprehensive view of gender-based influencer effects (Schouten, Janssen, & Verspaget, 2020). Delving deeper into audience segments and their preferences would uncover nuances in how distinct consumer groups respond to influencer messaging. The role of influencer authenticity, the impact of different content types, and the influence of cross-cultural variations could all be subjects of fruitful investigation (Lou & Yuan, 2019). Moreover, analyzing the long-term consequences of influencer trustworthiness on brand-consumer relationships and examining how influencer impact translates into actual purchase behavior could provide a more comprehensive understanding of the overall influencer marketing landscape (Sokolova & Kefi, 2020). By recognizing these shortcomings and considering new avenues for investigation, we may keep improving our comprehension of the intricate dynamics at play in influencer marketing, ultimately leading to more effective and nuanced strategies for brands in the fashion industry and beyond.

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Table.1:Demographic

		Frequency	Percent
Gender	Male	119	54
	Female	101	46
Age	Under18	4	1.82
	18-24years	111	50.00
	25-34years	99	45.00
	35-44years	4	1.82
	45-54years	2	0.90
EducationalQualification	Highschool	2	0.90
	Secondaryschool	10	4.55
	Bachelor'sdegree	92	41.82
	Master'sdegree	100	45.45
	Doctorate	16	7.27
occupation	Student	160	72.72
	Employed	50	22.72
	Unemployed	08	3.63
	Business	11	5
Socialmediausage	Daily	200	90.90
	Severaltimesaweek	8	3.63
	Severaltimesamonth	2	0.90
	Rarely	10	4.54
Mostusedsocialmediaplatform	Instagram	121	55
	Facebook	42	19
	Snapchat	20	9.1
	Twitter	14	6.4
	Others	23	10.5
Fashion Related Interests	ClothingandApparel	143	65
	Footwear	30	13.6
	Beautyandcosmetics	11	5
	Fashiontrends(Fast Fashion)	11	5
	Accessories(e.g.,Jewellery,bagsetc.)	15	6.18
	Luxuryfashion	10	4.5

Source: Author's analysis





Table.2: Reliability Results

Results of Reliability Test		
Dimension	No .of items	Cronbach Alpha(α)Value
InfluencerExpertise	05	.941
InfluencerTrustworthiness	05	.948
InfluencerAttractiveness	04	.914
InfluencerInformationQuality	03	.816
InfluencerAttributes	17	.885
BrandAwareness	04	.828
OverallScale	21	.900

Note: Cronbach Alpha (α) for all the constructs is above the threshold level.70

Table.3:Results of the Overall Measurement Model

Construct	Item	Factor Loading	CR	AVE
Influencer Expertise	E11	.971		
	E13	.904	0.942	0.768
	E15	.950		
	E12	.806		
	E14	.727		
	T2	.911		
Influencer Trust worthiness	T4	.947	0.948	0.786
	T3	.906		
	T5	.876		
	T1	.785		
	A2	.995		
Influencer Attractiveness	A4	.956	0.904	0.709
	A3	.660		
	A1	.704		
	IQ3	.794		
Influencer Information Quality	IQ2	.846	0.821	0.606
	IQ1	.688		
Brand Awareness	BA1	.823		
	BA4	.769	0.831	0.554
	BA2	.751		
	BA3	.620		

Table.4: Discriminant Validity Results

	CR	AVE	BA	IE	IT	IA	IIQ
BA	0.831	0.554	0.744				
IE	0.942	0.768	0.388	0.876			
IT	0.948	0.786	0.426	0.249	0.887		
IA	0.904	0.709	0.401	0.309	0.227	0.842	
IIQ	0.821	0.606	0.338	0.196	0.320	0.186	0.779

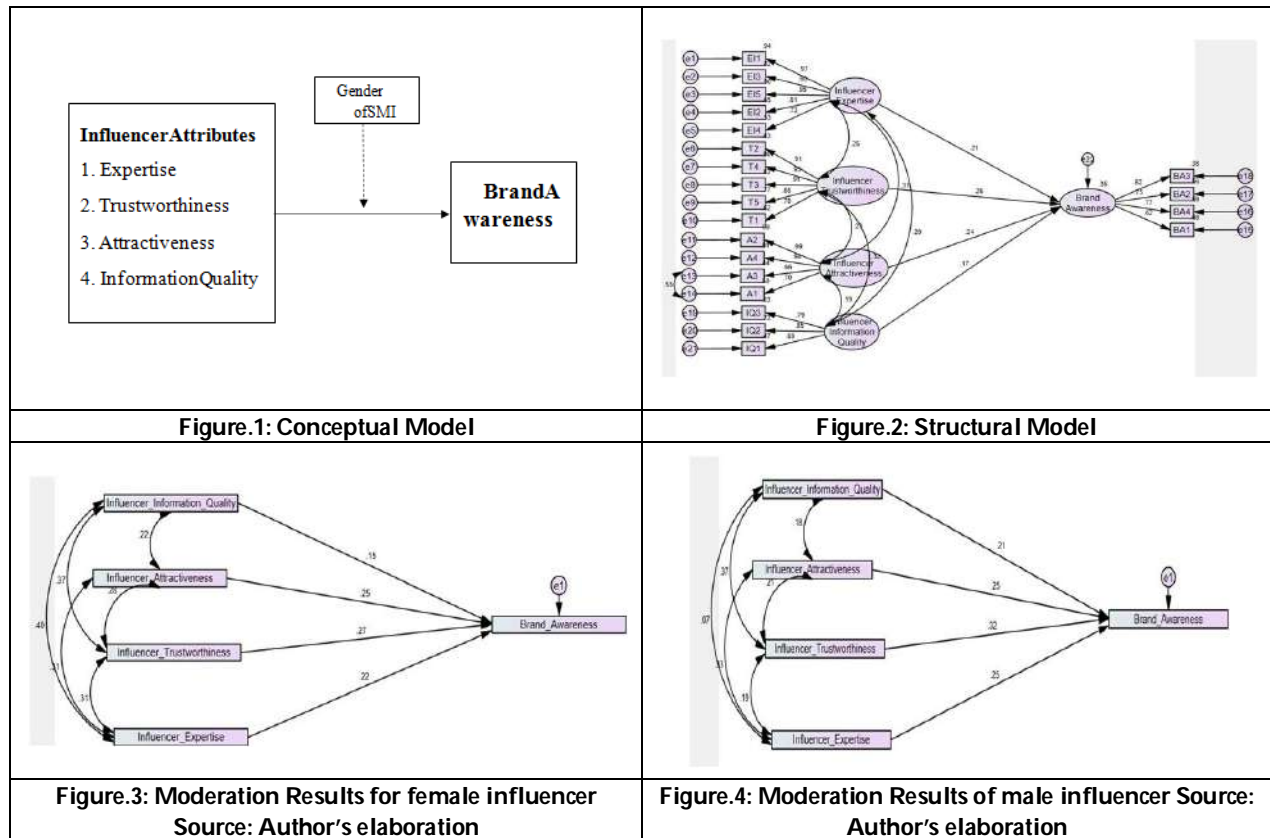




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Table.5: Hypotheses Results

		Estimate	S.E.	C.R.	P	Decision
Brand-Awareness	Information Quality	.175	.078	2.228	0.026	Supported
Brand-Awareness	Expertise	.195	.063	3.103	0.002	Supported
Brand-Awareness	Trustworthiness	.261	.059	3.722	0.000	Supported
Brand-Awareness	Attractiveness	.242	.059	3.595	0.001	Supported





Honey Preserve Dosage form of Internal Medicinal Drug in Siddha

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ABSTRACT

Pharmaceuticals of Siddha medicine is a well evolved branch and terrific emphasis is laid at the drug preparation and dosage forms. The health practitioner themselves by way of preparing the drugs and consequently had know-how approximately components and processing techniques. Each of the dosage shape that advanced no longer only address the factors like preservation, bioavailability, palatability but additionally extracing the preferred constituent from the uncooked material. Honey preserve is one of the maximum appreciated and valued herbal products added to humans considering that historical times. Honey is used no longer simplest as a nutritional product however also in health defined in conventional Siddha medicine. Some of the herbs vegetation, fruits, nuts and rizhomes are higher healing efficacy and their to be had only in season with a view to lead them to available for consumptions even in non seasons, they need to be preserved well via appropriate techniques. The ones which might be preserved on Honey have self life of 12 months.

Keywords: Honey preserve, Thenural, Siddha, Antioxidant, Honey.





INTRODUCTION

In Honey Preserve drugs like Ginger, Indian gooseberry, Terminalia chebula are Blanched in warm water. Pores are made in it after which soaked in Honey. They will additionally be soaked in sugar syrup or Honey. A number of the herbs flora, fruits, nuts and rizhomes are higher therapeutic efficacy and their to be had only in season as a way to cause them to available for consumptions even in non seasons, they have to be preserved well by means of appropriate techniques. Those which can be preserved in the salt solution, plant juices and the fruit juices are known as pakkuvam and people that preserved in the sugar syrup or Honey primarily based called Honey Preserve [1].32 styles of dosage form are lay down for oral drugs for every of dosage form have self lifes[2]. Honey preserve have selflife 12 months. This procedure of improvement resulted in use of temperature, pressure, catalyst appropriate combination of the Synergetic and antagonists ingredients.

METHOD OF PREPARATION

Big, matured, smooth and top fine culmination veggies elements are choosen and for making thenooral (Honey preserve) first unique styles of fruits/greens parts peeled or unpeeled are boiled in water and softened. The base of sugar or Honey of required to consistency is separately made. Thereafter the boiled fruits vegetable parts are soaked within the base for twenty-four hours. Next day if the base remains thin than required consistency and it is once more boiled until the specified consistency received. In Honey preserve, preserved Honey is an essential components as preservative and also posses dietary value.[2] Honey (thean) is a natural product it's far formed from nectar of flora by way of honeybees (Apis mellifera; own family: Apidae)[3]. Honey has been used by people on account that 5500 years [4]. Honey is a aggregate of Sugars and other compounds Honey additionally incorporate any quantity of numerous compounds to function as antioxidants which include chrsine, pinobanksin, Vitamin C, catalyse and pinocembrin[60- 73]. The unique composition of any batch of honey relies upon on the flowers available to the be as that produce the honey generally Honey evaluation display fructose-38.2 percent, glucose 31.3 percent, sucrose 1.31 %, maltose 7.1 percentage, water 17.2%, highest sugar 1.5 percent, ash 0.2 percent, different undetermined 3.2 percentage.Honey natural preservative Honey whilst appearing to be a liquid simply has very low water content material it consequently can keep the increase of water preferring bacteria are there that has been some medical research indicating the honey creates what's called speak the year against bacteria and the contamination which means that it create sticky barrier among itself .This chemical is constructed from activity from the enzyme glucose oxidase, which is clearly present in honey. This response occur more regularly in honey that has been kept out of direct sunlight. consequently whilst we are the usage of honey as a preservatives we a have to make sure Honey used as spent as plenty of its lifetime life span faraway from direct light resources.

Honey, while being capable of prevent bacteria invasion may be susceptible to damage through the fermentation due to better sugar content material certainly occurring in it. The fermentation process whilst, in the flip another substances that the honey is mixed with that fermentation procedure may be averted by way of making use of heat to Honey earlier than use. Even though there may be also some medical evidence to indicate that heat handled Honey is less powerful as preservatives than unprocessed Honey. The reasoning at the back of this it warmness gift inside the light that slows peroxide activity and not light itself [4,5].Instance Inji thenural (Zinger preserve), Nellikkai thenural (Phyllanthus emblica) kadukkai tenural (Terminalia chebula preserve) storage thenural are usually to be preserved in dry and a smooth Glass jar porcelain boxes under stored in hygienic circumstance in clean and dry locations. Maximum historic populace, including the Greeks, chinese, Romans, and Babylonians, Egyptians having a honey as each for dietary ambitions and for its medicinal uses.[Honey is the insect-derived herbal product, and it has therapeutic, dietary, cosmetic and therapeutic values Honey is a balanced weight loss plan for both male & woman in every age[6,7]. Honey no wishes to refrigerate, it in no way spoils, and it can additionally be hold at room temperature in a dry place [8,14] .The water interest of honey is among 0.56 and 0.62 and its value of pH is 3.9.Honey became utilized as a natural sweetener from it has high stage of fructose (honey is 25% sweeter than sugar)[16]. Furthermore, using honey in liquids [17]. Now a days, information on evidence suggests that honey can exert several



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health-useful results together with antioxidant, anti-diabetic, anti-bacterial, respiration, gastrointestinal, cardiovascular, and fearful protective effects[18-30].

The Lord has inspired the bees, to build their hives in hills, on timber, and in man's habitations, from inside their bodies comes a drink of various colors, in which is healing for human kind. Three hundred forms of honey have been recognized[33-40].

Nutritional And Non Nutritional Additives Of Honey

Major composition of honey is carbohydrates that make a contribution ninety five–ninety seven% of its dry weight. Moreover, honey consists of primary compounds, such as including eye sicknesses, bronchial asthma, Cough, throat infections, tuberculosis, thirst, hiccups, fatigue, dizziness, constipation, worm infestation, piles, eczema, recovery of ulcers, and wounds and honey used as adjuvant for drug management of medicine in conventional siddha remedy.[1,2,3,40-43] proteins, vitamins, amino acids, minerals, and organic acids pure honey also consists of flavonoids[44-48], polyphenols, lowering compounds, alkaloids, glycosides, cardiac glycosides, anthraquinone, and unstable compounds. Monosaccharides (fructose and glucose) are the most critical sugars of honey and may be contributed to the maximum of the nutritional and physical results of honey. similarly to monosaccharides, smaller quantities of disaccharides and oligosaccharides are found in honey . A lot of these sugars are formed throughout the honey ripening and maturation instances. Gluconic acid, a made of glucose oxidation, is the principle organic acid that is present in honey; in addition, small amounts of acetic acid , formic acid, and citric acid have been observed. It was used in treatment of several cancer [49-56] Those natural acids are chargeable for the acidic (pH between 3.2 and 4.5) assets of honey. Honey additionally consists of some essential amino acids, such as all 9 essential amino acids and all nonessential amino acids besides for asparagine and glutamine. Proline was suggested as the primary amino acid in honey, followed by different kinds of amino acids. Enzymes (diastase, invertases, glucose oxidase, catalase, and acid phosphatase) represent the primary protein substances of honey. Maximum of the water-soluble nutrients found in honey, with vitamin C. 31 variable minerals had been present in honey, along with all the most important minerals, together with phosphorus, sodium, calcium, potassium, sulfur, magnesium, and chlorine . Many critical trace additives like silicon (Si), rubidium, vanadium, zirconium, lithium, and strontium. Heavy metals including lead (Pb), cadmium (Cd), and arsenic (As) are gift as pollution.[35] previous studies have detected the about six hundred risky compositions in honey that make a contribution to its potential biomedical results. The volatile compounds of honey are generally low however encompass Flavonoids and polyphenols, which act as antioxidants, are two most important bioactive molecules present in honey. Latest proof has proven the presence of almost thirty styles of polyphenols in honey [57-65] .

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Unveiling the Ethnomedicinal Significance of Plants Utilization among Tribal Communities in Southern Pali District, Rajasthan, India

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ABSTRACT

The present study delves into the intricate web of ethnomedicinal knowledge held by the tribal communities residing in the remote landscapes of Pali district, Rajasthan, India. Conducted in 2021, the investigation aimed to document the indigenous utilization of medicinal plants, extending its reach across different seasons to capture a comprehensive spectrum of traditional remedies. Local inhabitants, seasoned elders, traditional herbalists and local vendors shared their insights, interwoven with the threads of ancient practices. The study amalgamated this experiential wisdom with literary consultations, revealing a diverse range of botanical solutions to various health challenges. The exploration encompassed remedies for fever, gastrointestinal disorders, skin ailments, kidney issues and respiratory infections. Each chapter unraveled the botanical identities, vernacular nomenclature, plant parts harnessed and methods of application. This revelation highlights the profound relationship between humans and their botanical companions, showcasing nature's role not only as a resource but also as a collaborator in healing. Ultimately, this study underscores the harmonious coexistence of traditional wisdom and contemporary inquiry, creating a bridge between the past, present and an enriched future of healthcare interwoven with nature's bounty.

Keywords: Ethno medicinal Knowledge, Tribal Communities, Traditional Remedies, Indigenous Medicinal Plants, Healthcare Traditions





INTRODUCTION

The progress and evolution of human civilization have long been intertwined, both consciously and unconsciously, with the natural environment, particularly the world of plants. Primitive societies, deeply connected to nature, heavily relied on their surroundings for survival. Through a process of trial and error, they acquired knowledge about the economic and medicinal properties of various plants. This indigenous knowledge became an integral part of the lives of communities dependent on their natural surroundings, particularly the tribal people, also known as Adivasis in India. Ethnobotany is a multidisciplinary field that demands proficiency in several areas, including botanical expertise for the proper identification and preservation of plant specimens, anthropological knowledge for comprehending cultural concepts around the perception of plants and linguistic competence for transcribing local terms and understanding native morphology, syntax and semantics (Anderson *et al.*, 2012). However, gaining precise knowledge from native healers can be challenging, as they may be hesitant to share their knowledge with outsiders. The world exhibits a vast diversity of biological resources and only a fraction of this potential has been explored. In certain regions, conserving natural biodiversity may be more beneficial than utilizing land for activities such as pasture or timber extraction. Identification of medicinal plants can be achieved through diverse methods, such as random screening, taxonomic sampling, or ethnobotanical collecting (Mulder and Coppolillo, 2005). Investigations have demonstrated that compounds derived from ethnobotanical research exhibit greater potency than those obtained through random screening, highlighting the high potential for product development.

Rajasthan is the largest state in India, with a population of approximately 12.44% belonging to various tribal communities such as Bhil, Bhil-Meena, Damor, Dhanka, Garasia, Kathodi, Kokna, Kolidhor, Naikara, Patelia, Meena and Seharja who reside in remote areas with limited access to basic infrastructure facilities (Sharma *et al.*, 2011). The state is also home to several nomadic tribes such as Banjara, Gadolia-Lohar, Kalbelia, Sikligar, Kanjar, Sansi and Bagri, which further enhance its ethnic heritage. These ethnic groups maintain close communication with one another, resulting in the sharing of ethnobotanical knowledge. In the southern Pali district of Rajasthan, India, a comprehensive exploration of plants possessing ethnomedicinal importance has revealed a wealth of traditional knowledge practiced by various tribal communities (Figure 1). These practices are documented in a study focusing on the herbal formulations employed by tribes in the region. The study highlights a diverse range of plant species and their medicinal uses within these indigenous communities. Among the documented plants, *Azadirachta indica*, commonly known as Neem, is utilized for its leaves in the form of poultices applied locally. This practice is particularly common among the Sahariya, Bhil, Kalbelia and Meena tribes. Similarly, the roots of *Calotropis procera* have been identified to be applied locally, with the plant being recognized among the Kalbelia and Garasia tribes. The *Areca catechu* plant holds significant importance, with its bark and flower tops being formulated into a juice infused with asafoetida. This preparation finds use among the Sahariya tribe. Another noteworthy plant is *Tecomella undulata*, whose bark and branches are chewed among the Bhil and Garasia tribes (Sharma and Kumar, 2011). The current investigation diligently undertook extensive efforts to gather and document the invaluable ethnomedicinal knowledge held by the tribal communities residing in the Pali district of Rajasthan. This endeavor was driven by a commitment to uncover, understand and preserve the traditional healing practices and remedies that have been passed down through generations within these indigenous populations. Through a combination of immersive fieldwork, participatory interactions and insightful observations, a comprehensive repository of ethnomedicinal information was compiled, reflecting the deep-rooted wisdom of the tribal peoples in the region.

MATERIALS AND METHODS

Study Area

The Pali district is situated between latitudes 24.45 to 26.29 North and longitudes 72.47 to 74.18 East (Figure 2). It shares its borders with eight districts of Rajasthan, creating a connection with various regions. To its north lie Nagaur and Jodhpur districts, while its southeastern boundary is shared with Udaipur and Rajasmand districts. Adjacent to the northeast is the Ajmer district, while its western border touches the Barmer district. Further, Sirohi and Jalore



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districts are positioned to the south and west, respectively. The district spans a total geographical area of 12,387 square kilometers. The climatic conditions of the study area, Pali district, demonstrate the arid to semi-arid nature of the region. The combination of high temperatures and low rainfall during certain periods of the year reflects the desert-like conditions that Rajasthan is known for. The reliance on the monsoonal rains for sustaining agriculture and water resources is evident from the observed rainfall patterns. The variations in relative humidity and temperature underscore the distinct seasons experienced by the region, with hot summers and relatively milder winters.

Survey

The majority of the surveys were conducted in the southern region of Pali district (mainly Bali tehsil), along with its neighboring areas in Rajasthan. In addition to the surveys, supplementary information was collected from secondary sources within the study area. The surveys conducted in the study area followed two primary approaches: intensive surveys involving in-depth examinations of one or two villages over a span of about a week and extensive surveys encompassing multiple villages or localities within the radius of a selected village-camp. The data collection process involved a combination of interviews, observations and active participation. According to the India census of 2011, the population of Bali stood at 19,880 individuals. Among this populace, males make up 50.67% (10,007), while females constitute 49.33% (9,873) of the total. Bali's average literacy rate is recorded at 64.28%, which falls below the national average of 74.04%. Specifically, 74.51% of males and 53.91% of females are literate. Notably, 11.72% of the total population is under the age of 6. Back in 1897, the population of Bali was around 6,000. The demographic makeup of Bali is primarily characterized by the Jain and Marwadi communities, which are also the most prosperous segments. However, a considerable number of individuals from these communities have relocated to various parts of India, engaging in business activities. Their visits to their ancestral town, such as Bali, are often centered around family marriage ceremonies. During the study, interviews were categorized into two types: individual and group interviews. In the case of individual interviews, people were chosen randomly while on the move or upon entering huts, engaging with knowledgeable individuals from the village alongside figures like the headman (Figure 3). Group interviews involved interacting with multiple individuals simultaneously after explaining our purpose. Despite initial hesitations from women, their active participation gradually emerged. These interviews were strategically conducted in diverse locations, including forest environments where tribal members were encouraged to discuss plant species' utility, particularly in group settings. Valuable insights were also gained from interviews held at the headman's hut or communal areas. Interviews at work sites were usually brief due to the tribal members' work commitments.

RESULTS AND DISCUSSION

To comprehensively document the utilization of indigenous medicinal plants, an extensive survey was conducted in the remote regions of Pali district, Rajasthan, India, throughout the year 2021. The survey was meticulously designed to encompass diverse seasons, thereby facilitating the collection of a wealth of information. The indigenous knowledge concerning the medicinal properties of native plants was systematically gathered through interactions with a range of sources, including local residents, seasoned elders from rural communities, practitioners of traditional herbal medicine and local vendors specializing in herbal remedies (Figure 4). This holistic approach ensured a comprehensive understanding of the plants' applications. The gathered insights were further substantiated by referencing relevant literature, thus adding a scholarly perspective to the documentation process. By amalgamating experiential wisdom with empirical validation, this endeavor seeks to preserve and share the rich heritage of indigenous plant-based medicine in the Pali district. Extensive documentation has been undertaken to capture the diverse array of plant-based formulations employed by the tribal communities inhabiting the study area. These formulations serve as remedies for a wide spectrum of health issues and are elaborated upon in the subsequent details (Table 1):





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Fever And Febrifuge

In the context of treating fever and its related symptoms, several ethnomedicinal plant-based formulations are employed by the local tribal communities (Figure 5). The botanical knowledge handed down through generations unveils a range of valuable remedies harnessing the potential of indigenous flora. One such remedy involves *Azadirachta indica* A. Juss., commonly known as Neem Tree or "Neem" in the local language. The fresh leaves of the Neem tree are harnessed by boiling them in water and the resulting infusion is ingested thrice a day to alleviate fever. Additionally, the practice of chewing 3-4 tender Neem leaves every morning supplements this treatment. *Calotropis gigantea* Linn., referred to as Milkweed or "Safed aak," is another botanical contender for treating fever. This shrub species contributes its flowers for medicinal use. Consumption of a single piece of the Milkweed flower with water is recommended once a day for a span of 3-4 days as part of the therapeutic protocol. The indigenous insights of tribal healers also encompass *Piper longum* Linn., known as Long Pepper or "Pipli." This herbaceous plant offers its fruits as the medicinal component. The traditional method entails immersing the Long Pepper fruits in clarified butter (ghee) overnight, followed by frying them with a dash of salt. The resulting preparation is then chewed, allowing for its potential febrifuge properties to be efficaciously conveyed. Harnessing the attributes of *Saccharum officinarum* Linn., commonly termed as Sugarcane or "Ganna," a distinctive medicinal tea is concocted for addressing fever-related discomfort. This involves the usage of dried ginger, cloves, tulsi leaves, tea leaves, jaggery (sugarcane juice candy) and milk. Consumed before bedtime, this herbal fusion amalgamates the healing properties of its constituents to provide a holistic approach to fever management.

Digestive And Gastrointestinal Disorder

Within the realm of digestive and gastrointestinal disorders, the indigenous knowledge of local tribal communities unveils an array of botanical solutions harnessed from the surrounding flora. These remedies stand as testaments to the intimate relationship between traditional healing practices and the rich diversity of plant life. *Aegle marmelos* (L.) **Correa**, commonly referred to as Wood apple or "Bael," takes center stage as a tree species contributing to these remedies. The fruit of the Bael tree is transformed into a therapeutic agent by being powdered and combined with *Foeniculum vulgare* Mill. (fennel) seed and isubgol. This formulation finds its application in addressing chronic dysentery. *Aerva javanica* (Burm.f.) Shult., known as Desert cotton or "Bui," is a herbaceous plant that plays a role in alleviating stomachache. The root of this plant is reduced to powder, which is then consumed with water, offering a potential remedy for such discomfort. *Aloe vera* (L.) Burm.f., recognized as Aloe vera or "Ganwar patha," is a herbaceous species. In this context, the leaves of the Aloe vera plant are ingested as a vegetable, with the intent of treating constipation. *Calotropis procera* (Ait.) R. Br., identified as Milkweed or "Aak," contributes its gynostegium for medicinal use. A paste of the gynostegium, rendered aqueous, is combined with a few drops of ghee and water. This preparation holds promise in relieving stomachache in children. *Capparis deciduas* (Forsk.) Edgew., known as Bare caper or "Ker," employs its root in addressing the health needs of patients suffering from typhoid. The root is transformed into an aqueous paste, administered with water to impart its potential therapeutic effects. The botanical offerings of *Citrullus colocynthis* (L.) Schrad, colloquially termed Bitter cucumber or "Tumba," are harnessed through dried fruit powder mixed with salt. This mixture is taken with water to mitigate stomachache. Additionally, the combination of dried fruit powder, black pepper and rock salt is used to alleviate constipation. *Crotalaria burhia* Buch.-Ham., referred to as Burhia rattlespod or "Khimp," presents its powdered roots as a remedy for stomachache. This root preparation, when taken with lukewarm water, offers a potential relief from the discomfort. *Cuminum cyminum* L., commonly known as Cumin or "Jeera," is an herbaceous plant whose seeds are employed in a decoction. This concoction, combined with rock salt and lemon juice, is administered to combat stomachache. Harnessing the properties of *Ferula asafetida* Linn., recognized as Asafoetida or "Hing," the latex of the plant is transmuted into a powder. This powder, mixed with water, serves as a massage for the abdomen and is also consumed to alleviate abdominal pain. *Ficus religiosa* L., known as Sacred fig or "Peepal," contributes its knots (stem galls) to address constipation. The dried powder of these knots is taken with water, offering a potential solution to this discomfort. The medicinal potential of *Foeniculum vulgare* Mill., referred to as Fennel or "Saunf," is harnessed through a mixture of its seed powder, Trigonella foenum-graecum (fenugreek) seed powder, F. asafetida (hing) and black salt. This combination, when consumed with water, serves as a means to manage acidity. *Indigofera cordifolia*, commonly termed Heart leaf indigo or "Gokhru," employs its seeds in addressing typhoid. A preparation involving the boiling

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of seeds and subsequent administration of the filtrate for three days is considered beneficial. *Lawsonia inermis* Linn., known as Heena or "Mehndi," employs its powdered seeds in collaboration with clarified butter. These components are amalgamated into small balls and consumed twice a day to address dysentery accompanied by mucus. *Mangifera indica* Linn., recognized as Mango or "Aam," offers a remedy for children experiencing diarrhea. A paste of crushed mango seed (giri) is combined with water or curd, presenting a potential solution to this discomfort. *Nelumbo nucifera* Gaertn., commonly referred to as Lotus or "Kamal," employs its seeds in a mixture composed of lotus seeds, a small amount of salt, Piper nigrum seeds and lemon juice. This mixture is provided to patients experiencing vomiting. *Polygonum plebeium* R. Br., known as Knotweed or "Lalbuti," employs its entire plant in the creation of a decoction used to address colic complaints. *Sarcostemma viminale* (L.) R. Br., recognized as Milk rope or "Khir-khimp," utilizes its plant extract to manage digestive disorders. *Terminalia chebula* Retz., referred to as Myrobalan or "Harad," utilizes slightly fried fruit powder as a remedy, taken with water. *Trachyspermum ammi* (Linn.) Sprague, commonly known as Carom or "Ajwain," employs a mixture of seed powder, a small amount of *F. asafoetida* (hing) and black salt. This preparation is consumed with water to address gastric problems. Finally, *Zingiber officinale* Rosc., recognized as Ginger or "Adrak," utilizes its rhizome in powdered form, mixed with a small amount of salt and consumed with water to alleviate abdominal pain. These ethnomedicinal practices underline the profound connection between local plant resources and the alleviation of digestive and gastrointestinal disorders within tribal communities.

Cold And Cough

Within the context of addressing diverse health concerns, the indigenous knowledge of local tribal communities draws upon an array of botanical resources, each offering distinctive remedies. *Allium sativum* Linn., commonly known as Garlic or "Lahsun," plays a significant role by utilizing roasted garlic flakes as a therapeutic agent (Figure 6). Administered before bedtime, these flakes are consumed and for children, a blend with jaggery is employed. *Brassica nigra*, recognized as Mustard or "Saron," employs a unique method of administration. Two drops of mustard oil are placed into the nostrils, potentially harnessing its beneficial properties. *Cicer arietinum* L., known as Chickpea or "Channa," utilizes chickpea powder (besan) in its remedy. Roasted and added to milk with sugar, this mixture is consumed before bedtime. *Coriandrum sativum* Linn., commonly referred to as Coriander or "Dhaniya," employs the decoction of coriander seeds in its approach. *Curcuma longa*, recognized as Turmeric or "Haldi," employs the vibrant rhizome. A half teaspoon of turmeric powder, when combined with warm milk, becomes an evening ritual with potential health benefits. *Justicia adhatoda* Linn., known as Malabar nut or "Adusa," capitalizes on its leaves. A decoction made from finely crushed dry leaves, complemented by mishri (sugar candy) and ginger, is ingested thrice a day. *Ocimum sanctum* Linn., commonly referred to as Basil or "Tulsi," takes its flowers into medicinal service. A decoction consisting of 5-6 flowers, along with jaggery and turmeric, is administered before bedtime. *Phoenix dactylifera* Linn., recognized as Dates or "Khajoor/Chuaar," employs dried dates as a resource. Boiling these dates with milk offers a remedy taken before bedtime. *Trachyspermum ammi* (Linn.), commonly known as Carom or "Ajwain," presents a unique approach. Seeds roasted on an iron frying pan are wrapped in cloth, enabling patients to inhale their beneficial vapors. *Zingiber officinale* Rosc., identified as Ginger or "Adrak," harnesses the juice of its fresh rhizome. Administered three times a day, mixed with honey, this concoction holds potential in promoting health.

Heart Disease

A compilation of indigenous medicinal practices reveals a variety of plant-based interventions. *Allium sativum* Linn., commonly known as Garlic or "Lahsun," a herb from the Alliaceae family, is administered as boiled flakes mixed with milk, often consumed in the early morning. Another valuable resource is *Embolia officinalis* Gaertn., also known as Aonla or "Aamla," a tree from the Euphorbiaceae family. Its fruit, when dried and combined with sugar candy (mishri), is ingested with water. The *Ficus religiosa* L., Sacred fig or "Peepal," a tree from the Moraceae family, employs its green leaves. Boiling 15 leaves in a glass of water until reduced to one-third creates a solution taken in three doses throughout the day. Furthermore, *Terminalia arjuna* Roxb., known as Arjuna or "Arjun," a tree belonging to the Combretaceae family, employs its bark. Powdered bark, mixed with clarified butter or milk, is consumed twice or thrice daily for a span of 15 days. These insights underscore the diverse ways in which indigenous plants are harnessed for health and well-being in the Pali district.





Kidney And Urination Problem

Addressing kidney and urination problems through indigenous botanical solutions unveils a spectrum of plant-based interventions. *Acacia nilotica* (L.) Delile, commonly known as Arabic tree or "Babool," is a tree from the Mimosaceae family. Its leaves, when finely mixed with *Pedaliium murex* (gokhru) and kalmi shora, offer a remedy when taken before bedtime. *Boerhavia diffusa* L., the red spiderling or "Lal sathi," a herb from the Nyctaginaceae family, offers diuretic effects when its leaves are cooked and consumed as a vegetable. *Corbichonia decumbens* (Forssk.) Jacq ex Exell, known as Prostrate purslane or "Pathar-chatti," employs crushed leaves to address kidney stone problems. *Coriandrum sativum* Linn., Coriander or "Dhaniya," a herb from the Apiaceae family, requires boiling its seeds in water to produce a liquid that combats urination issues. *Ocimum basilicum* Linn., Forest basil or "Ban tulsi," a herb from the Lamiaceae family, utilizes sprouted seeds consumed with curd to alleviate urinary problems. *Pedaliium murex* Linn., commonly called Caltrops or "Gokhru," a herb from the Pedaliaceae family, relies on boiled fruit filtrate as a diuretic. *Ricinus communis* L., Castor or "Arandi," a shrub from the Euphorbiaceae family, involves boiling seeds in milk and consuming the preparation to address kidney problems. Lastly, *Sesamum indicum* L., Sesame or "Til," a herb from the Pedaliaceae family, recommends a mixture of seed powder and jaggery powder to be consumed before sleep. These diverse botanical approaches illuminate the intricate synergy between indigenous plant knowledge and kidney-related wellness.

Skin Problems

Unveiling botanical solutions for skin-related ailments reveals an array of indigenous interventions. *Azadirachta indica* A. Juss., commonly known as Neem Tree or "Neem," a tree from the Meliaceae family, advocates applying an aqueous paste of neem leaves or using neem leaf-infused water for bathing to alleviate skin irritation. *Calotropis procera* (Ait.) R. Br., the Milkweed or "Aak," a shrub from the Asclepiadaceae family, suggests using ash from fresh root tips mixed with butter to treat eczema-affected areas. *Cynodon dactylon* Pers., Couch grass or "Doob," an herb from the Poaceae family, encourages applying a paste of the whole plant on eczema-prone skin. *Justicia adhatoda* Linn., the Malabar nut or "Adusa," a tree from the Acanthaceae family, advocates a paste prepared from boiled roots and leaves to be applied twice daily for eczema relief. *Ocimum sanctum* Linn., Basil or "Tulsi," a herb from the Lamiaceae family, recommends applying a paste of its leaves to eczema-affected areas. *Polygonum plebeium* R. Br., Knotweed or "Lalbuti," an herb from the Polygonaceae family, underscores applying a mixture of plant ash and oil to address eczema. *Psoralea corylifolia* Linn., Psoralea or "Bavachi," a herb from the Fabaceae family, suggests a mixture of soaked seeds, dried fruit powder of *Embllica officinalis* and mishri soaked in water for leucoderma treatment. *Terminalia catappa* Linn., Malabar almond or "Jangli badam," a tree from the Combretaceae family, recommends applying a paste of tender leaves to soothe eczema-prone areas. These botanical insights illuminate the harmony between indigenous plant wisdom and holistic skin wellness.

Respiratory Tract Infection And Lungs Complaint

Navigating the realm of respiratory tract infections and lung ailments, indigenous remedies emerge as guardians of well-being. *Achyranthus aspera* Linn., the Chaff-flower or "Apaamarga" from the Amaranthaceae family, introduces the practice of smoking dry apaamarga leaves for asthma relief, coupled with administering ash from burnt dry plants mixed with honey. *Amaranthus viridis* L., the Amaranth or "Chaulai," a herb from the Amaranthaceae family, recommends boiling its seeds and providing the resulting filtrate to pneumonia patients. *Calotropis procera* (Ait.) R. Br., the Milkweed or "Aak," a shrub from the Asclepiadaceae family, advocates a blend of ash from 5 gm of flowers sealed in an earthenware pot with honey for asthmatic individuals. *Citrullus colocynthis* (L.) Schrad., the Bitter cucumber or "Tumba," a climber from the Cucurbitaceae family, prescribes taking ash from the fruit with water to mitigate asthma. *Ficus glomerata* Roxb., the Fig or "Gular," a tree from the Moraceae family, proclaims the fusion of carom seed, nutmeg, cloves and jaggery with plant latex for liver complaints and diabetes. *Azadirachta indica* A. Juss., the Neem Tree or "Neem," a tree from the Meliaceae family, signifies consuming one teaspoon of dried fruit powder with water twice a day to potentially regulate sugar levels. *Boerhavia diffusa* L., the Red spiderling or "Lal sathi," a herb from the Nyctaginaceae family, introduces wearing garlands made of stem pieces resembling beads around the neck to aid in jaundice recovery. *Capparis decidua* (Forsk.) Edgew., the Bare caper or "Ker," a shrub from the Capparaceae family, suggests consuming a fine powder of approximately 3 cm of root with water for liver ailment





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mitigation. *Nyctanthes arbor-tristis* Linn., the Jasmine or "Harsingar," a shrub from the Oleaceae family, proposes the consumption of one teaspoonful of leaf powder with water on a daily basis. *Saccharum officinarum* Linn., the Sugar cane or "Ganna," an herb from the Poaceae family, endorses offering sugar cane juice to jaundice patients. *Trigonella foenum-graecum* Linn., the Fenugreek or "Methi," a herb from the Fabaceae family, underscores the intake of one teaspoon of dried seed powder early in the morning with water. This intricate tapestry of indigenous botanical interventions nurtures respiratory and lung well-being with nature's wisdom. Traditional knowledge within local tribal communities has led to the utilization of various plant-based formulations to address a range of health issues. These remedies draw upon the medicinal properties of indigenous flora, although their efficacy may not always be substantiated by scientific evidence. Among the health concerns addressed, fever and febrifuge remedies employed four plants, with plant parts such as fresh leaves, tender leaves, flowers and various components from plants like ginger, cloves, tulsi leaves, tea leaves, jaggery and milk being used. For digestive and gastrointestinal disorders, an extensive 21 plants were harnessed, utilizing various plant parts such as fruits, seeds, roots and leaves. Health issues such as dysentery, stomachache, constipation and acidity were targeted. Cold and cough remedies encompassed 10 plants, using diverse plant parts including roasted garlic flakes, mustard oil, chickpea powder, coriander seeds, turmeric powder, dry leaves, flowers, dried dates, roasted seeds and fresh rhizome juice (Figure 3 and 4). Heart disease interventions featured four plants, with plant parts like boiled garlic flakes, dried fruit (e.g., Aonla), boiled green leaves and powdered bark utilized. Nine plants were employed for kidney and urination problems, with plant parts ranging from leaves to roots, seeds and powders. Lastly, skin problems were addressed using eight plants, incorporating neem leaves, ash from root tips, whole plant paste, boiled roots and leaves, basil leaves paste, plant ash and oil mixture, soaked seeds and dried fruit powder and tender leaves paste. In the context of respiratory tract infections and lung complaints, 10 plants were employed, including dry apaamarga leaves, boiled seeds, ash from flowers, ash from the fruit and various ingredient fusions, aiming to alleviate issues like asthma and pneumonia. It's important to exercise caution and consult healthcare professionals when considering traditional or herbal treatments, particularly for severe health conditions, as the effectiveness of these remedies can vary and scientific validation may be necessary.

CONCLUSION

In culmination, the study embarks on a profound journey through the ethnomedicinal tapestry of indigenous plants, unveiling a treasure trove of traditional remedies nurtured by the communities in the remote areas of Pali district, Rajasthan, India. The meticulous survey conducted across seasons served as a compass, steering the research towards a panoramic understanding of plant utilization for diverse health concerns. Through engagement with local inhabitants, seasoned elders, traditional herbalists and local vendors, a mosaic of indigenous knowledge emerged, adorned with the pearls of ancient practices. This tapestry of wisdom was woven further by consulting literature, enriching the study's fabric with holistic insights. Diving into specific health realms, the study illuminated the intricate remedies for fever and febrifuge, digestive and gastrointestinal disorders, kidney and urination problems, skin afflictions and respiratory tract infections. Each chapter, a chapter of life in itself, delved into the botanical identities, local nomenclature, plant parts harnessed and modes of administration for ailments that have crossed paths with human existence since time immemorial. Remarkably, these indigenous remedies unveiled the symbiotic relationship between humans and their botanical cohabitants. The study's revelations emphasize the wisdom ingrained in local cultures, where nature is not merely a resource, but a partner in healing. This journey into the ethnomedicinal realm stands as a testament to the harmonious coexistence of traditional knowledge and modern exploration, providing a bridge between past and present and paving the way for a more enriched future where the synergy between nature and health is cherished and safeguarded.

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Table.1: Indigenous botanical remedies by local tribal communities in Southern Pali district

Sr. no.	Plant Name	Plant Part Used	Health Category	Used by Tribe
1	<i>Azadirachta indica</i> A. Juss. (Neem)	Fresh leaves, Tender leaves	Fever and febrifuge	Bhil
2	<i>Calotropis gigantea</i> Linn. (Milkweed)	Flowers	Fever and febrifuge	Garasia
3	<i>Piper longum</i> Linn. (Long Pepper)	Fruits	Fever and febrifuge	Bhil
4	<i>Saccharum officinarum</i> Linn. (Sugarcane)	Various components	Fever and febrifuge	Garasia
5	<i>Aegle marmelos</i> (L.) Correa (Wood apple)	Fruit	Digestive and gastrointestinal	Bhil
6	<i>Aerva javanica</i> (Burm.f.) Shult. (Desert cotton)	Root	Digestive and gastrointestinal	Garasia





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7	<i>Aloe vera</i> (L.) Burm.f.	Leaves	Digestive and gastrointestinal	Bhil
8	<i>Calotropis procera</i> (Ait.) R. Br. (Milkweed)	Gynostegium	Digestive and gastrointestinal	Garasia
9	<i>Capparis decidua</i> (Forsk.) Edgew. (Bare caper)	Root	Digestive and gastrointestinal	Garasia
10	<i>Citrullus colocynthis</i> (L.) Schrad. (Bitter cucumber)	Dried fruit powder	Digestive and gastrointestinal	Bhil
11	<i>Crotalaria burhia</i> Buch. -Ham. (Burhia rattlepod)	Root	Digestive and gastrointestinal	Bhil
12	<i>Cuminum cyminum</i> L. (Cumin)	Seeds	Digestive and gastrointestinal	Bhil
13	<i>Ferula asafetida</i> Linn. (Asafoetida)	Latex	Digestive and gastrointestinal	Bhil
14	<i>Ficus religiosa</i> L. (Sacred fig)	Knots (stem galls)	Digestive and gastrointestinal	Meena & Bhil
15	<i>Foeniculum vulgare</i> Mill. (Fennel)	Seed powder	Digestive and gastrointestinal	Meena & Bhil
16	<i>Indigofera cordifolia</i> (Heart leaf indigo)	Seeds	Digestive and gastrointestinal	Bhil
17	<i>Lawsonia inermis</i> Linn. (Heena)	Powdered seeds with clarified butter	Digestive and gastrointestinal	Garasia
18	<i>Mangifera indica</i> Linn. (Mango)	Crushed mango seed paste	Digestive and gastrointestinal	Bhil
19	<i>Nelumbo nucifera</i> Gaertn. (Lotus)	Seeds	Digestive and gastrointestinal	Meena & Bhil
20	<i>Polygonum plebeium</i> R. Br. (Knotweed)	Entire plant	Digestive and gastrointestinal	Meena & Bhil
21	<i>Sarcostemma viminale</i> (Milk rope)	Plant extract	Digestive and gastrointestinal	Garasia
22	<i>Terminalia chebula</i> Retz. (Myrobalan)	Fruit powder	Digestive and gastrointestinal	Garasia
23	<i>Trachyspermum ammi</i> (Carom)	Seed powder	Digestive and gastrointestinal	Bhil
24	<i>Zingiber officinale</i> Rosc. (Ginger)	Rhizome in powdered form	Digestive and gastrointestinal	Bhil
25	<i>Allium sativum</i> Linn. (Garlic)	Roasted garlic flakes	Cold and cough	Garasia
26	<i>Brassica nigra</i> (Mustard)	Mustard oil in nostrils	Cold and cough	Meena & Bhil
27	<i>Cicer arietinum</i> L. (Chickpea)	Chickpea powder in milk with sugar	Cold and cough	Bhil
28	<i>Coriandrum sativum</i> Linn. (Coriander)	Decoction of coriander seeds	Cold and cough	Garasia
29	<i>Curcuma longa</i> (Turmeric)	Turmeric powder with warm milk	Cold and cough	Bhil
30	<i>Justicia adhatoda</i> Linn. (Malabar nut)	Decoction of dry leaves	Cold and cough	Garasia
31	<i>Ocimum sanctum</i> Linn. (Basil)	Decoction of basil flowers	Cold and cough	Garasia
32	<i>Phoenix dactylifera</i> Linn. (Dates)	Boiled dates with milk	Cold and cough	Bhil
33	<i>Trachyspermum ammi</i> (Carom)	Inhaling vapors of roasted seeds	Cold and cough	Meena & Bhil





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34	<i>Zingiber officinale</i> Rosc. (Ginger)	Fresh rhizome juice mixed with honey	Cold and cough	Bhil
35	<i>Allium sativum</i> Linn. (Garlic)	Boiled garlic flakes mixed with milk	Heart disease	Garasia
36	<i>Emblca officinalis</i> Gaertn. (Aonla)	Dried fruit with sugar candy (mishri)	Heart disease	Garasia
37	<i>Ficus religiosa</i> L. (Sacred fig)	Boiled green leaves	Heart disease	Meena & Bhil
38	<i>Terminalia arjuna</i> Roxb. (Arjuna)	Powdered bark with clarified butter or milk	Heart disease	Meena & Bhil
39	<i>Acacia nilotica</i> (Arabic tree)	Leaves mixed with <i>Pedaliu murex</i> and kalmi shora	Kidney and urination problems	Garasia
40	<i>Boerhavia diffusa</i> L. (Red spiderling)	Leaves as a vegetable	Kidney and urination problems	Bhil
41	<i>Corbichonia decumbens</i> (Prostrate purslane)	Crushed leaves	Kidney and urination problems	Meena & Bhil
42	<i>Coriandru sativum</i> Linn. (Coriander)	Seeds boiled in water	Kidney and urination problems	Bhil
43	<i>Ocimum basilicu</i> Linn. (Forest basil)	Sprouted seeds with curd	Kidney and urination problems	Garasia
44	<i>Pedaliu murex</i> Linn. (Caltrops)	Boiled fruit filtrate	Kidney and urination problems	Garasia
45	<i>Ricinus communis</i> L. (Castor)	Seeds boiled in milk	Kidney and urination problems	Garasia
46	<i>Sesamum indicu</i> L. (Sesame)	Seed powder and jaggery powder	Kidney and urination problems	Meena & Bhil
47	<i>Azadirachta indica</i> A. Juss. (Neem)	Aqueous paste of neem leaves or neem leaf-infused water	Skin problems	Bhil
48	<i>Calotropis procera</i> (Milkweed)	Ash from fresh root tips mixed with butter	Skin problems	Garasia
49	<i>Cynodon dactylon</i> Pers. (Couch grass)	Paste of the whole plant	Skin problems	Bhil
50	<i>Justicia adhatoda</i> Linn. (Malabar nut)	Paste of boiled roots and leaves	Skin problems	Meena & Bhil
51	<i>Ocimum sanctu</i> Linn. (Basil)	Paste of basil leaves	Skin problems	Meena
52	<i>Polygonu plebeiu</i> R. Br. (Knotweed)	Mixture of plant ash and oil	Skin problems	Meena & Bhil
53	<i>Psoralea corylifolia</i> Linn. (Psoralea)	Mixture of soaked seeds, dried fruit powder and mishri	Skin problems	Bhil
54	<i>Terminalia catappa</i> Linn. (Malabar almond)	Paste of tender leaves	Skin problems	Garasia
55	<i>Achyranthus aspera</i> Linn. (Chaff-flower)	Smoking dry apaamarga leaves, ash with honey	Respiratory tract infection and lungs	Meena & Bhil
56	<i>Amaranthus viridis</i> L. (Amaranth)	Boiling seeds and	Respiratory tract	Garasia





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		providing the filtrate	infection and lungs	
57	<i>Calotropis porcera</i> (Milkweed)	Blend of ash from flowers sealed with honey	Respiratory tract infection and lungs	Bhil
58	<i>Citrullus colocynthis</i> (Bitter cucumber)	Ash from the fruit with water	Respiratory tract infection and lungs	Garasia
59	<i>Ficus glomerata</i> Roxb. (Fig)	Fusion of carom seed, nutmeg, cloves and jaggery with plant latex	Respiratory tract infection and lungs	Meena & Bhil
60	<i>Azadirachta indica</i> A. Juss. (Neem)	Consuming dried fruit powder with water	Respiratory tract infection and lungs	Bhil
61	<i>Boerhavia diffusa</i> L. (Red spiderling)	Wearing garlands made of stem pieces around the neck	Respiratory tract infection and lungs	Garasia
62	<i>Capparis decidua</i> (Bare caper)	Consuming a fine root powder with water	Respiratory tract infection and lungs	Garasia
63	<i>Nyctanthes arbor-tristis</i> Linn. (Jasmine)	Consuming leaf powder with water	Respiratory tract infection and lungs	Bhil
64	<i>Saccharum officinarum</i> Linn. (Sugar cane)	Offering sugar cane juice to jaundice patients	Respiratory tract infection and lungs	Garasia
65	<i>Trigonella foenum-graecum</i> Linn. (Fenugreek)	Intake of seed powder with water	Respiratory tract infection and lungs	Bhil

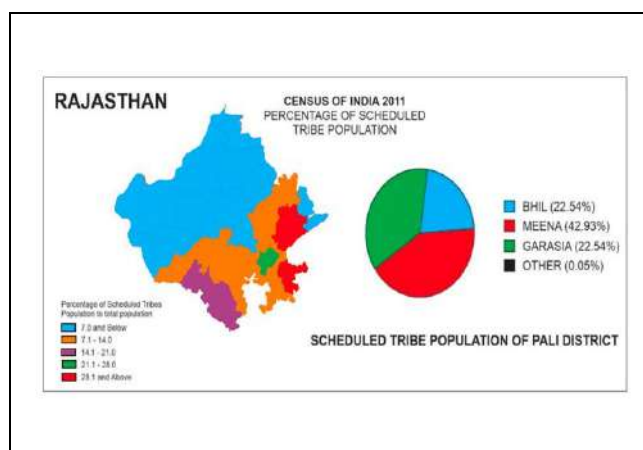


Figure.1: Rajasthan map showing percentage of scheduled tribe population

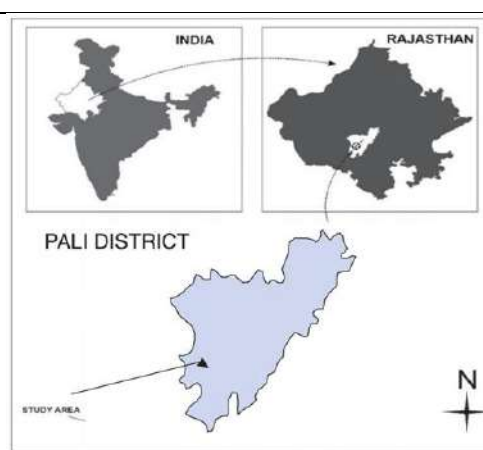
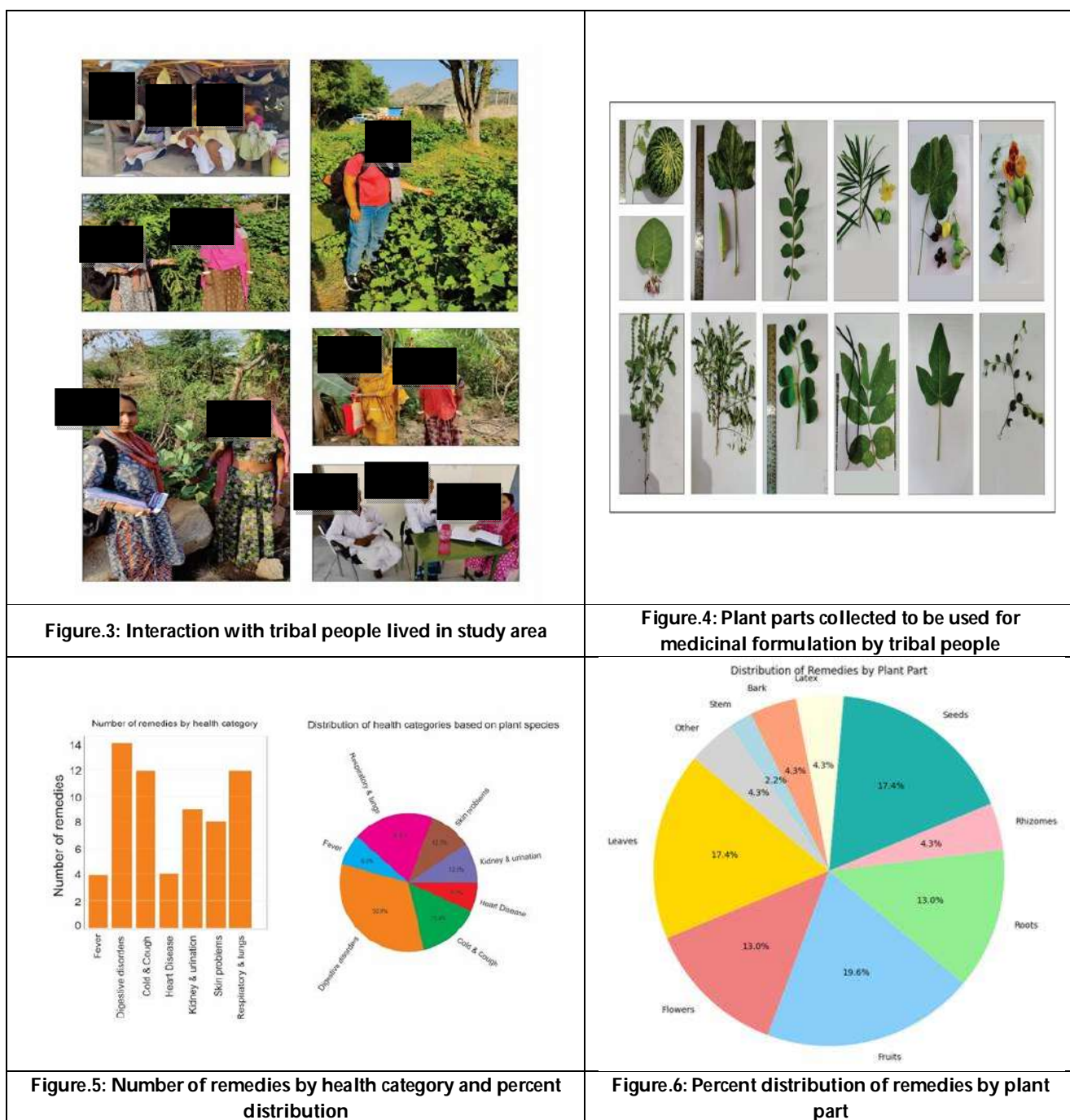


Figure.2: Map showing the location of the study area within Pali district, Rajasthan, India.







Evaluating the Contribution in Financial Literacy in Influencing Investment Behaviour amongst Millennial Trendy Bengaluru

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ABSTRACT

The research centers on three major areas of financial literacy with respect to millennials and their decision making. The ability to make financial decisions and take on appropriate financial measures, is in most cases accompanied by a strong understanding of financial concepts. The study considers the various investment choices of the millennials in the context of their financial literacy, enclosing the unique economic opportunities and challenges that they usually experience. The contribution of this study is also in the mind of the millennials to be more practical when making decisions and deciding how to use the knowledge acquired in the financial literacy training with regards to speculation behavioral decision making. There is also a need for better financial management and investing in education to look at the achieve their goals in the long run. The study's outcomes are sought to assist in the enhancement of financial literacy and responsible investment among millennials in Bengaluru, India for officials, teachers, monetary institutions, and other stakeholders.

Keywords: Financial Decision, Financial Planning, Investments, Investment Behavior, Financial Literacy.

INTRODUCTION

Today, with the constantly changing financial landscape, prudent investment options, risks involved, and potential returns are more important than ever. This is especially so for millennials, people born between 1981 and 1996, who face both unique financial challenges and opportunities. It ensures that individuals are armed with the skills to make more informed decisions in either the classical investment options offered by stocks and bonds or those newer ones



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found in cryptocurrencies and peer-to-peer lending. Lack of such a foundation leads most people into problems such as creating unnecessary debt, failing to save enough, and spending poorly. These issues not only affect their particular financial stability but also have broader economic implications. For millennials, especially those looking forward to achieving financial freedom and generating wealth, financial literacy becomes an essential convert. It enables the individual to set realizable financial goals, assess risk appropriately, and develop sustainable financial habits. As digital natives, many millennials, however, face core financial issues, particularly regarding risk assessment, investment strategy, and retirement planning. Atkinson and Macy (2012) argue that financial behavior plays a key role; for example, people who have a negative view of saving are less likely to prepare for long-term goals such as retirement. Similarly, financial literacy broadly influences how individuals allocate resources, with psychological factors such as emotional biases and risk tolerance influencing their choices. Despite the growing awareness of financial literacy, many Indian millennials struggle to apply their knowledge effectively, especially in urban areas such as Bangalore. The survey shows that there is a significant gap between understanding financial concepts and their application in real-life scenarios. To address this gap, targeted financial education initiatives are needed that focus on practical application, empowering millennials to make better financial decisions and contribute to the country's broader economic growth.

RESEARCH GAP

Previous studies have examined financial literacy and its impact on financial outcomes, but few have focused on how its three key components—knowledge, behavior, and attitude—shape investment decisions. This is particularly true for urban millennials in Bengaluru, a demographic group facing unique financial challenges.

RESEARCH QUESTIONS

1. What are the prevailing levels of financial literacy amongst millennials in Bengaluru?
2. In what ways does financial literacy affect the investment behavior of Bengaluru's millennials?

RESEARCH OBJECTIVES

1. To judge the financial literacy levels of Bengaluru's millennial population, with a emphasis on their financial knowledge, behaviors, and attitudes.
2. To analyze how financial literacy impacts the investment patterns of millennials living in Bengaluru.

Conceptual Framework

Independent Variables: Financial Literacy

- **Financial Knowledge:** Understanding of financial concepts, tools, and resources.
- **Financial Behavior:** The actual financial practices, such as budgeting, saving, and investing.
- **Financial Attitude:** Individual's mindset towards managing money and financial decision-making.

Dependent Variable: Investment Behavior

RESEARCH METHODOLOGY

The study investigates the connection between financial literacy and the investment behavior of millennials in Bengaluru. A stratified random sampling method is employed to select 200 respondents aged between 25 and 40. Primary data is gathered using structured questionnaires, while secondary data is sourced from existing studies. The analysis incorporates both descriptive and inferential statistical techniques to evaluate financial literacy levels and demographic characteristics.



**Murali and Nasa Dhanraj****Data Analysis**

The descriptive statistics indicate a diverse sample with some variability across most demographic variables. Gender, age, and education show relatively low variation, suggesting a somewhat uniform distribution in these areas. Employment status and income reveal greater diversity, with respondents having a wider range of employment situations and income levels. All respondents are investors, with varying amounts invested and a broad selection of investment options. The frequency of investments and the factors influencing investment decisions show moderate variation, indicating different investment behaviors and motivations among participants. Overall, the data suggests a heterogeneous group in terms of employment, income, and investment choices.

Reliability Analysis

The Cronbach's Alpha values for the variables indicate the reliability of the scales used to measure financial literacy components. Financial Knowledge ($\alpha = 0.878$) and Investment Behaviors ($\alpha = 0.858$) show strong internal consistency, suggesting that the items measuring these variables are highly reliable. Financial Behaviour ($\alpha = 0.832$) also demonstrates good reliability, although slightly lower than the previous two. Financial Attitude ($\alpha = 0.717$), while still acceptable, shows a somewhat lower level of consistency compared to the other variables.

Factor Analysis

With a KMO value of 0.631, which is considered acceptable, the data shows enough correlations to proceed with analysis. Bartlett's Test reveals a significant Chi-square value of 466.228 with $df = 3$ and a p-value of 0.000.

Correlation Analysis

The correlation analysis reveals that **Financial Knowledge (FK)** has a strong positive relationship with **Investment Behavior (IB)** ($r = 0.944$), suggesting that better financial knowledge leads to more informed investment choices. It is also closely linked with **Financial Behavior (FB)** ($r = 0.733$) and **Financial Attitude (FA)** ($r = 0.988$), indicating that individuals with more financial knowledge tend to display better financial behavior and attitudes. Additionally, **Financial Behavior (FB)** and **Financial Attitude (FA)** are both significantly correlated with **Investment Behavior (IB)** ($r = 0.914$ and $r = 0.926$, respectively), implying that positive financial behaviors and attitudes foster proactive investment habits.

Regression Analysis

The regression model shows a strong relationship between Financial Knowledge, Financial Behaviour, Financial Attitude, Income, and Investment Behaviour. The model explains 81.3% of the variance in Investment Behaviour, indicating a good fit. The predictors are statistically significant, and the model's residuals are independent, as indicated by the Durbin-Watson value. Overall, the analysis confirms that these factors strongly influence Investment Behaviour.

ANOVA ANALYSIS

The regression model, which incorporates financial knowledge, financial behaviour, financial attitude, & income, substantially clarifies the variation in investment behaviour, according to the ANOVA analysis. The factors that predict it significantly explain the variation, as evidenced by the large F-statistic of 85.205 and the overall variation of 125.529. The model's statistical significance is confirmed by the p-value of less than 0.05, which indicates that the predictors taken together significantly influence investment behaviour. According to the findings, this model is very significant since the predictors taken together appear to have a substantial impact on investment behaviour.

Findings

- The data reveals a diverse sample with moderate variation in employment, income, and investment behaviors. Most respondents are investors with varying amounts invested and a range of investment options. Gender, age, and education are relatively evenly distributed.
- The scales measuring Financial Knowledge, Financial Behavior, and Investment Behavior exhibit strong. Financial Attitude shows acceptable reliability ($\alpha = 0.717$), though slightly lower.



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- Strong correlations between the variables and a KMO score of 0.631 and a significant Bartlett's Test result ($p < 0.05$) indicate that the data is appropriate for factor analysis.
- This suggests that people who have better financial behaviours, more financial knowledge, and more positive attitudes regarding money are able to engage in proactive investment behaviour.
- Financial Knowledge encompasses the most positive association with Investment Behaviour, followed by Financial Behaviour and Financial Attitude, both of which are highly significant.
- 81.3% of the variation in investment behaviour, indicating that financial behaviour, financial knowledge, financial attitude, as well as income all significant indicators of investment behaviour.
- The regression model's strong significance ($p < 0.05$) is confirmed by the ANOVA analysis, suggesting that the variables taken together significantly influence investment behaviour.

Suggestions

- First, Financial Education programs are essential, as Financial Knowledge has a strong influence on Investment Behavior.
- Widespread financial literacy initiatives can help individuals improve their investment knowledge. Second, promoting Positive Financial Behavior through programs that encourage regular savings, budgeting, and disciplined financial practices could enhance both investment habits and financial attitudes.
- Policy Recommendations suggest that policymakers should focus on initiatives that improve financial inclusivity and foster positive attitudes toward investment, especially among lower-income groups, as Income and Financial Attitude play significant roles.
- Lastly, Targeted Financial Guidance that provides personalized advice, focusing on enhancing both Financial Knowledge and Financial Attitudes, could encourage more individuals to become informed and proactive investors.

CONCLUSION

The study emphasises how important financial knowledge, financial behaviour, as fit as financial attitude are in determining how people invest. According to the data study, these variables together with income account for a significant amount of the variation in investment behaviour. The factor analysis validates that the data is appropriate for additional statistical investigation, and the measurement scales have a high degree of dependability. The significance of these characteristics is emphasised by both regression and ANOVA analyses, which validate their high potential for prediction for investment behaviour. Thus, promoting sound financial practices and raising financial knowledge might be useful tactics for improving people's investing habits.

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Table:1 Reliability Analysis

Sl No	Variables	N of Items	Cronbach's Alpha
1	Financial Knowledge	4	0.878
2	Financial Behaviour	5	0.832
3	Financial Attitude	5	0.717
4	Investment Behaviour	8	0.858

Table: 2 Factor Analysis

KMO and Bartlett's Test ^a		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.631
Bartlett's Test of Sphericity	Approx. Chi-Square	466.228
	Df	3
	Sig.	.000
a. Based on correlations		




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Table:3 Correlation Analysis

Correlations					
		FK	FB	FA	FL
FK	Pearson Correlation	1	.733**	.988**	.944**
	Sig. (2-tailed)		.000	.000	.000
	N	200	200	200	200
FB	Pearson Correlation	.733**	1	.698**	.914**
	Sig. (2-tailed)	.000		.000	.000
	N	200	200	200	200
FA	Pearson Correlation	.988**	.698**	1	.926**
	Sig. (2-tailed)	.000	.000		.000
	N	200	200	200	200
IB	Pearson Correlation	.944**	.914**	.926**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	200	200	200	200
**. Correlation is significant at the 0.01 level (2-tailed).					

Table:4 Regression Analysis

Model Summary ^b										
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.902 ^a	.813	.803	.489	.813	85.205	5	98	.000	2.045
a. Predictors: (Constant), Financial Knowledge, Financial Behavior, Financial Attitude, Income										
b. Dependent Variable: Investment Behavior										





Table:5 ANOVA ANALYSIS

ANOVA ^a						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	102.053	5	20.411	85.205	.000 ^b
	Residual	23.476	98	.240		
	Total	125.529	103			
a. Dependent Variable: Investment Behaviour						
b. Predictors: (Constant), Financial Knowledge, Financial Behaviour, Financial Attitude, Income						

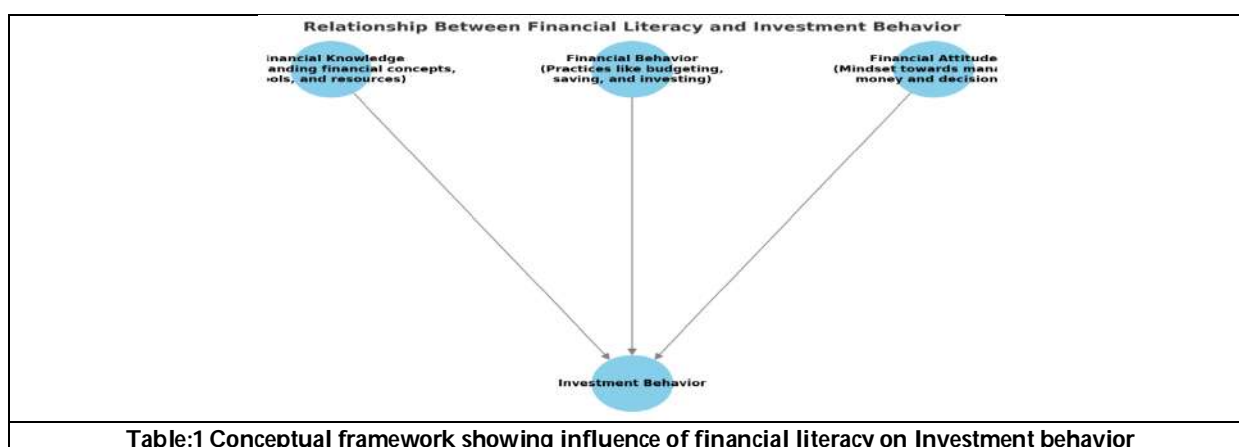


Table:1 Conceptual framework showing influence of financial literacy on Investment behavior





The Role of Blockchain Technology in Smart Contracts : A Boon or A Bane?

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ABSTRACT

Blockchain technology has ushered in transformative changes in the realms of digital security and transparency, particularly through the implementation of smart contracts. These self-executing agreements, which are inscribed on a blockchain, have the potential to enhance and secure transactions across diverse sectors by removing the necessity for intermediaries and lowering transaction expenses. By capitalizing on the decentralized and cryptographically secure characteristics of blockchain, smart contracts facilitate improved transparency and immutability, rendering them advantageous for industries such as finance, real estate, and supply chain management. Nonetheless, despite their promising attributes, smart contracts encounter considerable obstacles. Scientific and technical challenges, including scalability issues, susceptibility to programming errors, and the irreversible nature of blockchain transactions, pose significant concerns regarding their broader adoption. Furthermore, legal and regulatory frameworks often lag behind this rapidly evolving technology, leading to potential risks related to enforceability and accountability. As the blockchain landscape continues to develop, it is imperative to address these scientific and legal hurdles to fully harness the advantages of smart contracts. This article examines the complex nature of blockchain-based smart contracts, assessing whether they represent a significant advancement or a potential drawback for contemporary digital transactions.

Keywords: Blockchain, Technology, Contract, Law, Cryptography



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INTRODUCTION

In the continuously changing realm of digital advancement, blockchain technology has established itself as a fundamental element of contemporary computational frameworks, signaling the onset of a new age characterized by enhanced transparency and security in transactional processes. Fundamentally, blockchain operates as a decentralized ledger that enables the permanent recording of data across numerous nodes, guaranteeing that once information is recorded, it remains unchangeable and cannot be erased[1]. This fundamental technology has facilitated the emergence of smart contracts—automated agreements that are encoded directly into the blockchain. Smart contracts serve to automate and uphold contractual commitments, thereby decreasing the reliance on intermediaries and substantially lowering transaction expenses[2]. The appeal of smart contracts is rooted not only in their operational efficiency but also in their capacity to foster trust between involved parties. By offering a verifiable and immutable record of transactions, they reduce the risks typically associated with the enforcement of conventional contracts[3]. The adoption of smart contracts is on the rise across various sectors, including finance and supply chain management, as organizations seek to enhance operational efficiency and promote accountability [4]. Nevertheless, the implementation of smart contracts faces significant hurdles. Issues related to legal enforceability, potential coding flaws, and the intricacies of adhering to regulatory requirements pose substantial challenges that need to be addressed [5]. As we further investigate the function of blockchain technology within the context of smart contracts, it is essential to evaluate the numerous advantages alongside the associated risks. This analysis seeks to clarify whether the integration of blockchain and smart contracts represents a significant advancement for innovation or a source of challenges laden with complexities.

The Various Technologies Used In Blockchain Analysis

Blockchain technology is fundamentally supported by a range of sophisticated technologies that collectively enable its distinctive features. Central to blockchain is cryptographic hashing, which plays a crucial role in ensuring the integrity and security of data. Hash functions, such as SHA-256, transform input data into a fixed-length string of characters, rendering it exceedingly difficult to reverse-engineer or modify the original data without detection [6]. This essential security mechanism is vital for fostering trust within a decentralized framework. Another significant component is consensus algorithms, which dictate the processes by which transactions are verified and incorporated into the blockchain. Notable consensus mechanisms include Proof of Work (PoW) and Proof of Stake (PoS). PoW, utilized by Bitcoin, necessitates that participants solve intricate mathematical challenges, thereby securing the network and authenticating transactions [7]. Conversely, PoS selects validators based on the quantity of coins they possess and are prepared to "stake," presenting a more energy-efficient option [8]. Smart contracts, which are self-executing agreements embedded within the blockchain, signify another technological innovation. They automate the execution of contracts when specific conditions are satisfied, thereby reducing the reliance on intermediaries and improving efficiency [9]. Furthermore, decentralized applications (DApps) utilize blockchain technology to offer various services without centralized oversight, further illustrating the adaptability of this technology [10]. Interoperability technologies, including cross-chain protocols, enable communication and data sharing among different blockchain networks. This functionality is crucial for establishing a more interconnected ecosystem, thereby enhancing the broader application and utility of blockchain technology.

The Intricate Relationship Between Smart Contracts And Blockchain Analysis

The advent of blockchain technology has significantly transformed numerous industries by offering novel solutions to longstanding issues related to trust and verification. One of the most impactful applications of this technology is the development of smart contracts—automated agreements where the terms are encoded directly into software. The relationship between smart contracts and blockchain is complex, marked by the interaction of transparency, security, efficiency, and the associated challenges that these advancements present [11]. Fundamentally, a smart contract operates as a computer program that autonomously enforces and fulfills contractual obligations once specific conditions are satisfied. This level of automation substantially decreases the reliance on intermediaries, which in turn lowers transaction costs and enhances operational efficiency. By leveraging blockchain technology, smart contracts



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benefit from its decentralized and immutable characteristics, ensuring that once a contract is executed, its outcomes remain unchanged and secure. This feature bolsters the integrity of agreements and cultivates trust among the involved parties, as the execution of the contract is verifiable by all members of the network [12]. The interdependence of smart contracts and blockchain is evident in their fundamental attributes. Blockchain provides a secure and transparent environment for the implementation of smart contracts, with each contract stored on a distributed ledger that is accessible to all participants in the network. This decentralized framework mitigates the risk of single points of failure, thereby enhancing the overall resilience of the system [13]. Additionally, the transparency inherent in blockchain technology enables all stakeholders to verify the conditions and results of contracts, further reinforcing trust and accountability. From a technical perspective, the interplay between smart contracts and blockchain technology is fundamentally anchored in the consensus mechanisms that regulate the blockchain. These mechanisms are essential for ensuring that all participants reach a consensus on the legitimacy of transactions, which is vital for the proper functioning of smart contracts. For example, in a blockchain that employs Proof of Work (PoW), miners are responsible for validating transactions and subsequently executing smart contracts by confirming that the conditions outlined in the code are satisfied [14]. Conversely, Proof of Stake (PoS) systems adopt a different methodology, permitting validators to authenticate transactions based on the quantity of cryptocurrency they possess, thereby prioritizing economic investment over computational resources.

Despite the numerous benefits, the fusion of smart contracts and blockchain technology presents several challenges. A significant concern is the risk of coding errors. The reliability of smart contracts is directly linked to the quality of their underlying code [15]. Any defect in the code can result in unforeseen consequences, which may be exploited by malicious individuals. The notorious DAO hack in 2016 serves as a stark reminder of this vulnerability, where attackers took advantage of a flaw in the smart contract code, leading to substantial financial losses and underscoring the imperative for thorough testing and auditing of smart contracts [16]. Additionally, the legal recognition of smart contracts remains uncertain in various jurisdictions. Although the technology offers a powerful means of automating transactions, issues of enforceability emerge in the event of disputes. Conventional legal systems often find it challenging to adapt to the distinctive features of smart contracts, highlighting the need for the creation of new legal frameworks that can effectively tackle these issues [17]. This convergence of law and technology is an emerging area of research, prompting scholars and practitioners to work together in formulating guidelines for the effective deployment of smart contracts. Legal ambiguities, alongside scalability challenges, present considerable barriers to the broad implementation of smart contracts. As user numbers and transaction volumes rise, many blockchain networks face congestion, resulting in prolonged processing times and increased transaction costs. Such conditions can impede the effective deployment of smart contracts in contexts that demand swift execution [18]. Various solutions, including layer-two protocols and sharding, are under investigation to mitigate these challenges; however, they necessitate additional research and development [19]. Moreover, the potential for ethical challenges should not be disregarded. The automation that characterizes smart contracts may create situations where outcomes disproportionately impact specific stakeholders, especially in critical sectors like finance and healthcare. It is essential for developers to take ethical considerations into account during the design process of smart contracts to avoid unintentionally reinforcing biases or inequalities [20]. The interplay between smart contracts and blockchain technology is both significant and transformative, presenting remarkable prospects for enhancing efficiency, transparency, and security in contractual arrangements. Nevertheless, the obstacles—ranging from coding flaws to legal uncertainties—must be carefully addressed to realize the full promise of this innovative relationship. As academics, technologists, and legal professionals work together to tackle these challenges, the future of smart contracts and blockchain holds the potential to fundamentally alter the realm of digital transactions and agreements.

The Pros And Cons Of Smart Contracts Using Blockchain Analysis

Smart contracts, powered by blockchain technology, mark a revolutionary shift in how agreements are formed and upheld. By streamlining processes and fostering trust among involved parties, smart contracts have the potential to reshape numerous sectors. However, like any new technology, they come with their own set of pros and cons.

One of the standout advantages of smart contracts is their capacity for automation. Once the specified conditions are fulfilled, the contract executes automatically, eliminating the need for human oversight and significantly speeding up



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transaction processing times. This level of automation enhances operational efficiency, allowing businesses to redirect their focus toward more strategic initiatives. Additionally, smart contracts reduce the necessity for intermediaries, such as brokers or notaries, which leads to a notable decrease in transaction costs [21]. This is especially beneficial in fields like real estate and finance, where traditional methods often involve hefty fees. The decentralized aspect of blockchain further minimizes the overhead costs tied to managing multiple parties in a transaction [22]. Blockchain analysis offers an additional advantage. Smart contracts function on a transparent blockchain, allowing all involved parties to access identical information. This level of transparency builds trust, enabling stakeholders to independently confirm the contract's terms and its execution. Furthermore, the unchangeable nature of blockchain records guarantees that once a contract is executed, it remains intact, thereby reinforcing the integrity of the agreement [23]. Smart contracts utilize cryptographic algorithms for security, which significantly reduces the risk of fraud and hacking. Additionally, the decentralized structure of blockchain provides an added layer of protection, eliminating any single point of failure. As a result, it becomes exceedingly challenging for malicious individuals to alter contract information [24]. While smart contracts offer numerous benefits, their reliability hinges entirely on the quality of the underlying code. Any mistakes or security flaws can result in unexpected consequences, leaving them open to exploitation. A notable example is the infamous hack of The DAO in 2016, which led to the theft of millions of dollars, highlighting the dangers tied to inadequately programmed smart contracts [25]. The legal standing of smart contracts is still ambiguous in numerous jurisdictions. Although these contracts operate automatically, their enforceability can be questioned within conventional legal systems.

Courts might find it difficult to decipher the terms embedded in a smart contract, which can result in disagreements regarding intent and execution [26]. This uncertainty in the legal landscape may discourage businesses from embracing smart contracts. With the increasing adoption of blockchain technology, scalability has become a major hurdle. Numerous blockchain networks, especially those utilizing Proof of Work (PoW) consensus mechanisms, face difficulties when handling high transaction volumes. This results in sluggish processing times and rising fees during times of peak activity. Such constraints can impede the effective use of smart contracts in dynamic settings [27]. The use of smart contracts for automated decision-making brings forth significant ethical dilemmas. For example, if the underlying code contains biases, it could lead to the unfair treatment of specific individuals or groups. Additionally, the strict adherence to predetermined conditions might ignore unique situations that could influence results, which could ultimately result in unjust outcomes for those affected [28]. Smart contracts, driven by blockchain technology, bring numerous benefits such as automation, lower costs, enhanced transparency, and improved security. Nevertheless, it is essential to recognize the potential risks, including coding flaws, legal uncertainties, scalability challenges, and ethical dilemmas. As this technology advances, tackling these issues will be vital to unlocking the complete capabilities of smart contracts across different sectors.

A Comparative Analysis Of Traditional Contracts And Smart Contracts

Traditional contracts have historically served as the foundation of legal agreements, relying heavily on manual procedures, intermediaries [29], and mechanisms for legal enforcement. In contrast, smart contracts, which operate on blockchain technology, present considerable improvements in terms of efficiency, cost savings, and enforceability. Smart contracts facilitate the automatic execution of agreements once specific conditions are satisfied, thereby significantly decreasing the time needed for transaction processing. Unlike traditional contracts, which typically involve numerous steps and various parties, smart contracts simplify processes by removing the need for intermediaries. This automation not only speeds up transactions but also reduces the potential for human error.

The financial advantages of smart contracts are particularly noteworthy. By eliminating intermediaries such as lawyers or notaries, smart contracts can lead to a substantial decrease in transaction costs [30]. In contrast, traditional contracts often incur significant legal fees and administrative costs, rendering them less cost-effective, particularly for intricate agreements. Although smart contracts provide an immutable record of transactions on the blockchain, their legal status remains somewhat unclear. Traditional contracts, which are governed by established legal frameworks, offer more definitive pathways for dispute resolution and enforcement [31]. Smart contracts may encounter challenges regarding enforceability due to differing interpretations and a lack of legal recognition in certain jurisdictions [32].



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When assessing various blockchain platforms, Ethereum and Hyperledger emerge as prominent options for executing smart contracts. Ethereum, a public blockchain, enables developers to create decentralized applications with sophisticated smart contract capabilities, utilizing its powerful programming language, Solidity [33]. In contrast, Hyperledger provides a private blockchain framework that emphasizes enterprise solutions, prioritizing confidentiality and scalability [34]. While Ethereum is recognized for its versatility and community support, Hyperledger offers customized solutions for specific business needs.

Future Prospects And Innovations In The Smart Contract Domain

The future of smart contracts is characterized by significant potential, propelled by ongoing technological innovations and advancements. A notable trend is the incorporation of artificial intelligence (AI) within smart contracts, which allows for the analysis of data and the capacity to make real-time decisions in response to changing conditions [35]. This synergy may result in more adaptive contracts that automatically adjust to new circumstances.

Another promising area for development is the interoperability among diverse blockchain platforms. Initiatives aimed at creating cross-chain solutions will facilitate seamless interactions of smart contracts across multiple blockchain ecosystems, thereby enhancing their functionality and expanding their range of applications [36]. Furthermore, improvements in regulatory frameworks are expected to establish clearer standards for the enforceability of smart contracts, which will encourage wider adoption by businesses [37]. The rise of decentralized finance (DeFi) applications is also anticipated to broaden the scope of smart contracts, enabling intricate financial transactions to occur without intermediaries, thus transforming conventional financial services [38]. As these advancements progress, smart contracts are poised to become increasingly essential across various industries, including finance and supply chain management, fundamentally altering the execution and enforcement of agreements.

CONCLUSION

The investigation into the function of blockchain technology within smart contracts uncovers a multifaceted environment characterized by both potential benefits and significant obstacles. On one side, smart contract present remarkable advantages, such as improved efficiency, reduced costs, increased transparency, and enhanced security. Their capacity to automate transactions and remove the need for intermediaries fundamentally alters the execution of agreements, fostering trust and accountability among involved parties. Conversely, the adoption of smart contracts is fraught with challenges. Problems including coding flaws, legal uncertainties, and issues related to scalability pose considerable hurdles to their widespread implementation. Additionally, the absence of well-defined regulatory guidelines complicates the situation, causing many organizations to approach this technology with caution. Ultimately, the determination of whether blockchain technology in smart contracts serves as a benefit or a detriment depends on the effectiveness with which these challenges are navigated. As the technology progresses, collaboration among technologists, legal professionals, and policymakers will be essential in crafting a future where smart contracts can realize their transformative capabilities. By addressing the complexities inherent in this innovative framework, stakeholders can leverage the advantages of blockchain technology while minimizing its associated risks, thereby fostering a more efficient and just contractual environment.

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A Generalization of New Two - Parameter Xrama Distribution and its Application in using Survival Data

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ABSTRACT

In this study, a weighted transformation technique in Xrama distribution is employed to apply a two-parameter Xrama distribution on life-time data. Its statistical properties were investigated, including the mean residual life function, reliability function, hazard rate, reverse hazard function, stochastic ordering, order statistics, and moments-related measures. The MLE technique is used to estimate parameters. An actual lifetime cancer dataset was used to test the weighted Xrama distribution's goodness of fit, and it was found to fit the data better than other competing distributions.

Keywords: Weighted technique, Xrama distribution, mean residual function, Stochastic ordering, Moments.

INTRODUCTION

Weighted distributions are used in many scientific areas, including biomedicine, reliability, ecology, and branching processes. To represent this type of data, a variety of continuous distributions such as Weibull, Lindley, exponential, lognormal, and gamma are used. If x is the initial observation with its pdf $f(x)$, then in the event of sampling bias, an appropriate weighted function, say $w(x)$, a random variable function, will be introduced to reflect the scenario. Fisher developed the concept of weighted distributions to model ascertainment bias. Rao later extended this concept in a





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more cohesive approach while modeling statistical data when standard distributions were unable to represent these observations with equal probabilities. Dey *et al.* explored the weighted exponential distribution's properties and several estimation methods. Kilany obtained the weighted form of the lomax distribution. Patil and Rao researched the statistical applications of weighted distributions in human population and ecology. Shanker described a one-parameter Pratibha distribution with statistical features and applications. Several scholars have developed weighted versions of one parameter lifespan distributions using the weight function $w(x, \omega) = x^{\omega-1}$. For example, Ghitany *et al.* suggested weighted Lindley distribution (WLD) from Lindley distribution, Eyob and Shanker proposed weighted Garima distribution (WGD) from Shanker distributions, Shanker and Shukla suggested weighted Sujatha distribution (WSD) from Shanker distribution, Shanker *et al.* proposed a weighted Komal distribution (WKD) from Shanker's Komal distribution, and a weighted Uma distribution (WUD) from Shanker's Uma distribution, respectively. It has been observed that, depending on the conceptual or applied angle, these weighted distributions did not produce an adequate fit in certain datasets. As a result, searching for a better weighted distribution that matches to the most recent lifetime distribution is required. In this paper, we introduce a new two-parameter distribution. The proposed distribution is a weighted xrama. Harrison O. Etaga *et al.* (2023) proposed the xrama distribution, a new one-parameter lifetime distribution. The pdf and cdf functions of the suggested distribution, coupled with additional features, give an approach to MLE for estimating model parameters in the remainder of this study. When compared to several competing distributions, the suggested distribution (WXD) exhibits its flexibility and excellence in fitting several real-life cancer data sets.

Weighted Xrama Distribution (WXD)

The probability density function and cumulative distribution function of the WXD are defined in this section.

The Xrama distribution is a new one-parameter life time distribution. The Xrama distribution's pdf is provided by

$$f(x) = \frac{\theta^4}{(\theta^3 + 6)^2} (\theta^3 + 6x^3 + 12)e^{-\theta x} \quad x > 0, \theta > 0 \quad (1)$$

Additionally, the Xrama distribution's cdf is provided by

$$F(x) = 1 - \left\{ 1 + \frac{1}{(\theta^3 + 6)^2} (6\theta^3 x^3 + 18\theta^2 x^2 + 36\theta x) \right\} e^{-\theta x} \quad x > 0, \theta > 0 \quad (2)$$

A random variable x with a probability density function $f(x)$ has been examined. Let $w(x)$ be a weight function that is not negative. A new probability density function should be indicated.

$$f_w(x) = \frac{w(x)f(x)}{E(w(x))} \quad ; \quad x > 0$$

where $w(x)$ is the non-negative weight function, $E[w(x)] = \int w(x)f(x)dx < \infty$, and the associated random variable by X_w , also known as the weighted random variable corresponding to x . It is said that X_w is size-biased of order α when $w(x) = x^\alpha, \alpha > 0$. This type of selection process is known as size-biased sampling of order α . Size-biased (or weighted) data has a probability density function when $\alpha=1,2$.

$$f_w(x) = \frac{x^\alpha f(x)}{E(X^\alpha)}$$

The WXD is derived by applying the weighted function, which is $w(x) = x^\alpha$, on the Xrama distribution to get the WXD. Given the WXD, the probability density function is

$$f_w(x) = \frac{x^\alpha f(x)}{E(X^\alpha)} \quad ; \quad x > 0, \theta > 0, \alpha > 0 \quad (3)$$

Where

$$E(X^\alpha) = \int_0^\infty x^\alpha f(x) dx$$

After simplification we get

$$E(X^\alpha) = \frac{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12\alpha!}{\theta^\alpha (\theta^3 + 6)^2} \quad (4)$$

We can obtain the pdf of the WXD by substituting the values of equations (1) and (4) into equation (3).





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$$f_w(x) = \frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \quad (5)$$

After reduction, utilizing a lower incomplete gamma function results in

$$\gamma(z+1, \theta x) = \int_0^{\theta x} t^{(z+1)-1} e^{-t} dt$$

We shall get. The cdf for the weighted Xrama distribution is given by

$$F_w(x) = \int_0^x f_w(t) dt \quad (6)$$

After simplifying equation (6), we obtain the cdf of the WXD.

$$F_w(x) = \frac{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \quad (7)$$

Reliability Analysis

In this part, we will look at the reliability function, hazard rate, reverse hazard function, odds rate, mills ratio, and mean residual function for the proposed weighted Xrama distribution.

3.1 Survival function

$$S(x) = 1 - \left(\frac{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \right)$$

3.2 Hazard function

$$H(x) = \frac{f_w(x)}{S(x)}$$

$$H(x) = \frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!) - \theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}$$

3.3 Revers hazard rate

$$h_r(x) = \frac{f_w(x)}{F_w(x)}$$

$$h_r(x) = \frac{\left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \right)}{\left(\frac{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \right)}$$

$$h_r(x) = \frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}$$

3.4 Odds rate function

The weighted Xrama distribution's Odds Rate function is

$$O(x) = \frac{F_w(x)}{1 - F_w(x)}$$

$$O(x) = \frac{\left(\frac{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \right)}{1 - \left(\frac{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \right)}$$

3.5 Mills Ratio

$$\text{Mills Ratio} = \frac{1}{h_r(x)}$$

$$\text{Mills Ratio} = \frac{1}{\left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)} \right)}$$

3.6 Mean Residual function

$$M(x) = \frac{1}{s(x)} \int_x^\infty x f(x) dx - x$$





$$M(x) = \frac{1}{1 - \frac{\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!}} \int_x^\infty x \frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12)e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} - xM(x)$$

$$= \frac{1}{\frac{(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!) - (\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x))}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!}} \frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \int_x^\infty x^{\alpha+1} \theta^3 e^{-\theta x} dx$$

$$+ 6 \int_x^\infty x^{\alpha+4} e^{-\theta x} dx + 12 \int_x^\infty x^{\alpha+1} e^{-\theta x} dx$$

Put $\theta x = t, x = \frac{t}{\theta}, dx = \frac{dt}{\theta}$
 When $x \rightarrow 0, t \rightarrow 0$, and $x \rightarrow \infty, t \rightarrow \infty$
 After solving the integral, we get
 Upper incomplete gamma function

$$\Gamma(s, x) = \int_x^\infty t^{s-1} e^{-t} dt$$

$$M(x) = \frac{\theta^6 \Gamma(\alpha+2, \theta x) + 6\Gamma(\alpha+5, \theta x) + 12\theta^3 \Gamma(\alpha+2, \theta x)}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha! - (\theta^6 \gamma(\alpha+1, \theta x) + 6\gamma(\alpha+4, \theta x) + 12\theta^3 \gamma(\alpha+1, \theta x))} - x$$

Statistical Properties

In this section, we obtained the structural properties, the MGF, the characteristic function, and the r th Moment for the WXD random variables. Mean, variance, standard deviation, and harmonic mean are all explored.

4.1 Moments

If X is a random variable with WXD, the order moments $E(X^r)$ are as follows:

$$E(X^r) = \mu'_r = \int_0^\infty x^r f(x) dx$$

$$\mu'_r = \int_0^\infty x^r \left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12)e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \right) dx$$

$$\mu'_r = \frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!} \int_0^\infty x^{\alpha+r} (\theta^3 + 6x^3 + 12)e^{-\theta x} dx$$

$$\mu'_r = \frac{\theta^6 \Gamma(r+\alpha+1) + 6\Gamma(r+\alpha+4) + \theta^3 12\Gamma(r+\alpha+1)}{\theta^r (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!)} \quad (8)$$

The Mean of the WXD is determined by putting $r=1$ and $r=2$ in equation (8).

$$\mu'_1 = \frac{\theta^6 \Gamma(\alpha+2) + 6\Gamma(\alpha+5) + \theta^3 12\Gamma(\alpha+2)}{\theta^1 (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!)}$$

$$\mu'_2 = \frac{\theta^6 \Gamma(\alpha+3) + 6\Gamma(\alpha+6) + \theta^3 12\Gamma(\alpha+3)}{\theta^2 (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!)}$$

$$\text{Variance} = \mu'_2 - (\mu'_1)^2$$

$$\sigma^2 = \left(\frac{\theta^6 \Gamma(\alpha+3) + 6\Gamma(\alpha+6) + \theta^3 12\Gamma(\alpha+3)}{\theta^2 (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!)} \right) - \left(\frac{\theta^6 \Gamma(\alpha+2) + 6\Gamma(\alpha+5) + \theta^3 12\Gamma(\alpha+2)}{\theta^1 (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!)} \right)^2$$

$$\sigma^2 = \frac{(\theta^6 \Gamma(\alpha+3) + 6\Gamma(\alpha+6) + \theta^3 12\Gamma(\alpha+3))(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!) - (\theta^6 \Gamma(\alpha+2) + 6\Gamma(\alpha+5) + \theta^3 12\Gamma(\alpha+2))^2}{\theta^2 (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12\alpha!)^2}$$





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$$S.D(\sigma) = \frac{\sqrt{(\theta^6\Gamma(\alpha+3)+6\Gamma(\alpha+6)+\theta^3 12\Gamma(\alpha+3))(\theta^6\alpha!+6(\alpha+3)!+\theta^3 12\alpha!)-(\theta^6\Gamma(\alpha+2)+6\Gamma(\alpha+5)+\theta^3 12\Gamma(\alpha+2))}}{\theta(\theta^6\alpha!+6(\alpha+3)!+\theta^3 12\alpha!)}$$

Harmonic Mean

$$H.M = E\left(\frac{1}{x}\right)$$

$$H.M = \int_0^{\infty} \frac{1}{x} f_w(x; \theta, \alpha) dx$$

$$H.M = \int_0^{\infty} \frac{1}{x} \left(\frac{x^{\alpha} \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right) dx$$

$$H.M = \frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \int_0^{\infty} x^{-1} x^{\alpha} (\theta^3 + 6x^3 + 12) e^{-\theta x} dx$$

$$H.M = \frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \int_0^{\infty} x^{\alpha-1} (\theta^3 + 6x^3 + 12) e^{-\theta x} dx$$

$$H.M = \frac{\theta(\theta^6 \Gamma(\alpha) + 6\Gamma(\alpha+3) + \theta^3 12\Gamma(\alpha))}{(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!)}$$

Moment Generating function and Characteristic function

If X_i implies WXD, then the MGF of X is as follows:

$$M_X(t) = E(e^{tx})$$

$$M_X(t) = \int_0^{\infty} e^{tx} f(x) dx$$

Applying Taylor's series expansion

$$M_X(t) = \int_0^{\infty} \left(1 + tx + \frac{(tx)^2}{2!} + \frac{(tx)^3}{3!} + \dots \right) f(x) dx$$

$$M_X(t) = \int_0^{\infty} \sum_{j=0}^{\infty} \frac{t^j}{j!} x^j f(x) dx$$

$$M_X(t) = \sum_{j=0}^{\infty} \frac{t^j}{j!} \int_0^{\infty} x^j f(x) dx$$

$$M_X(t) = \sum_{j=0}^{\infty} \frac{t^j}{j!} \mu'_j$$

$$M_X(t) = \sum_{j=0}^{\infty} \frac{t^j}{j!} \frac{\theta^j \theta^6 \Gamma(j + \alpha + 1) + 6\Gamma(j + \alpha + 4) + \theta^3 12\Gamma(j + \alpha + 1)}{\theta^j (\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!)}$$

$$M_X(t) = \frac{1}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \sum_{j=0}^{\infty} \frac{t^j}{j!} \theta^j \theta^6 \Gamma(j + \alpha + 1) + 6\Gamma(j + \alpha + 4) + \theta^3 12\Gamma(j + \alpha + 1)$$

Similarly, the characteristic function of the WXD is





$$\phi_X(t) = M_X(it)$$

$$M_X(it) = \frac{1}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \sum_{j=0}^{\infty} \frac{it^j}{j! \theta^j} \theta^6 \Gamma(j + \alpha + 1) + 6 \Gamma(j + \alpha + 4) + \theta^3 12 \Gamma(j + \alpha + 1)$$

Order Statistics

In this part, we used the weighted Xrama distribution to compute the order statistics distributions.

Let $X_{(1)}, X_{(2)}, X_{(3)}, \dots, X_{(n)}$ be the order statistics of the random sample taken from weighted Xrama. The probability density function of r^{th} order statistics, $X_{(r)}$, is defined as.

$$f_{X(r)}(x) = \frac{n!}{(r-1)!(n-r)!} f_X(x) [F_X(x)]^{r-1} [1 - F_X(x)]^{n-r} \quad (9)$$

By combining equations (5) and (7) with equation (9), the probability density function of order statistics $X_{(r)}$ of the weighted Xrama distribution is obtained by

$$f_{X(r)}(x) = \frac{n!}{(r-1)!(n-r)!} \left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) \times \left(\frac{\theta^6 \gamma(\alpha + 1, \theta x) + 6 \gamma(\alpha + 4, \theta x) + 12 \theta^3 \gamma(\alpha + 1, \theta x)}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{r-1} \\ \times \left(1 - \frac{\theta^6 \gamma(\alpha + 1, \theta x) + 6 \gamma(\alpha + 4, \theta x) + 12 \theta^3 \gamma(\alpha + 1, \theta x)}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{n-r}$$

Thus, the pdf of higher order statistics, $X_{(n)}$ of the WXD can be derived as

$$f_{X(n)}(x) = \left(n \frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) \times \left(\frac{\theta^6 \gamma(\alpha + 1, \theta x) + 6 \gamma(\alpha + 4, \theta x) + 12 \theta^3 \gamma(\alpha + 1, \theta x)}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{n-1} \quad (10)$$

The pdf of the first order statistic $X_{(1)}$ of the WXD

$$f_{X(1)}(x) = \left(n \frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) \times \left(1 - \frac{\theta^6 \gamma(\alpha + 1, \theta x) + 6 \gamma(\alpha + 4, \theta x) + 12 \theta^3 \gamma(\alpha + 1, \theta x)}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{n-1} \quad (11)$$

Likelihood Ratio Test

This section uses the weighted Xrama distribution to derive the likelihood ratio test.

Consider $X_{(1)}, X_{(2)}, X_{(3)}, \dots, X_{(n)}$ as a random sample from the weighted Xrama distribution.

The null and alternative hypotheses are used to test the hypothesis.

$$H_0: f(x) = f(x; \theta) \quad \text{against} \quad H_1: f(x) = f_w(x; \alpha, \theta)$$

The following test statistics are used to determine if a randomly selected sample of size n originates from the Xrama distribution or the weighted Xrama distribution.

$$\Delta = \frac{L_1}{L_2} = \prod_{i=1}^n \frac{f_w(x_i; \alpha, \theta)}{f(x_i; \theta)}$$

$$\Delta = \prod_{i=1}^n \frac{\left(\frac{x_i^\alpha \theta^{\alpha+4} (\theta^3 + 6x_i^3 + 12) e^{-\theta x_i}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)}{\left(\frac{\theta^4}{(\theta^3 + 6)^2} (\theta^3 + 6x_i^3 + 12) e^{-\theta x_i} \right)}$$

$$\Delta = \prod_{i=1}^n \left(\frac{x_i^\alpha \theta^{\alpha+4} (\theta^3 + 6x_i^3 + 12) e^{-\theta x_i}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) \times \left(\frac{(\theta^3 + 6)^2}{\theta^4 (\theta^3 + 6x_i^3 + 12) e^{-\theta x_i}} \right)$$

$$\Delta = \left(\frac{\theta^\alpha (\theta^3 + 6)^2}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^n \prod_{i=1}^n x_i^\alpha$$

If we reject the null hypothesis, then





$$\Delta = \left(\frac{\theta^\alpha (\theta^3 + 6)^2}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^n \prod_{i=1}^n x_i^\alpha > k \quad (12)$$

Similarly, we also reject the null hypothesis, where

$$\Delta^* = \prod_{i=1}^n x_i^\alpha > k \left(\frac{\theta^\alpha (\theta^3 + 6)^2}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^n$$

$$\Delta^* = \prod_{i=1}^n x_i^\alpha > k^* \text{ where } k^* = \left(\frac{\theta^\alpha (\theta^3 + 6)^2}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^n$$

For large sample sizes (n), $2 \log \Delta$ is distributed as chi-squared variables with one degree of freedom. We rejected the null hypothesis when the probability value is given by $p(\Delta^* > \alpha^*)$, where $\alpha^* = \prod_{i=1}^n x_i^\alpha$ is less than level of significance and $\prod_{i=1}^n x_i^\alpha$ is the observed value of the statistics Δ^* .

Bonferroni And Lorenz Curves

In this portion, we obtained the Bonferroni and Lorenz curves from the weighted Xrama distribution.

$$B(p) = \frac{1}{p\mu} \int_0^q x f_w(x_i; \theta, \alpha) dx$$

And

$$L(p) = \frac{1}{\mu} \int_0^q x f_w(x_i; \theta, \alpha) dx$$

Where $q = F^{-1}(p); q \in [0, 1]$

And $\mu = E(X)$

Thus, the Bonferroni and Lorenz curves of our distribution are, determined by

$$\mu = \frac{\theta^6 \Gamma(\alpha + 2) + 6\Gamma(\alpha + 5) + \theta^3 12\Gamma(\alpha + 2)}{\theta^1 (\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)}$$

$$B(p) = \frac{1}{p \left(\frac{\theta^6 \Gamma(\alpha + 2) + 6\Gamma(\alpha + 5) + \theta^3 12\Gamma(\alpha + 2)}{\theta^1 (\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)} \right)} \int_0^q x \left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) dx$$

$$B(p) = \frac{1}{p \left(\frac{\theta^6 \Gamma(\alpha + 2) + 6\Gamma(\alpha + 5) + \theta^3 12\Gamma(\alpha + 2)}{\theta^1 (\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)} \right)} \times \left(\theta^3 \int_0^q x^{\alpha+1} e^{-\theta x} dx + 6 \int_0^q x^{\alpha+4} e^{-\theta x} dx + 12 \int_0^q x^{\alpha+1} e^{-\theta x} dx \right)$$

Put $\theta x = t, x = \frac{t}{\theta}, dx = \frac{dt}{\theta}$

When $x \rightarrow 0, t \rightarrow 0$, and $x \rightarrow q, t \rightarrow \theta q$

$$B(p) = \frac{1}{p \left(\frac{\theta^6 \Gamma(\alpha + 2) + 6\Gamma(\alpha + 5) + \theta^3 12\Gamma(\alpha + 2)}{\theta^1 (\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)} \right)} \times \left(\theta^3 \int_0^{\theta q} \left(\frac{t}{\theta} \right)^{\alpha+1} e^{-t} \left(\frac{dt}{\theta} \right) + 6 \int_0^{\theta q} \left(\frac{t}{\theta} \right)^{\alpha+4} e^{-t} \left(\frac{dt}{\theta} \right) + 12 \int_0^{\theta q} \left(\frac{t}{\theta} \right)^{\alpha+1} e^{-t} \left(\frac{dt}{\theta} \right) \right)$$

After solving the integral, we get

$$B(p) = \frac{(\theta^6 \gamma(\alpha + 2, \theta q) + 6\gamma(\alpha + 5, \theta q) + 12\theta^3 \gamma(\alpha + 2, \theta q))}{p(\theta^6 \Gamma(\alpha + 2) + 6\Gamma(\alpha + 5) + 12\theta^3 \Gamma(\alpha + 2))} \quad (13)$$

$$L(p) = pB(p)$$

$$L(p) = \frac{(\theta^6 \gamma(\alpha + 2, \theta q) + 6\gamma(\alpha + 5, \theta q) + 12\theta^3 \gamma(\alpha + 2, \theta q))}{(\theta^6 \Gamma(\alpha + 2) + 6\Gamma(\alpha + 5) + 12\theta^3 \Gamma(\alpha + 2))} \quad (14)$$





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Stochastic Ordering

Stochastic ordering is a useful tool in finance and dependability to evaluate model performance. Let X and Y be two random variables with pdf, cdf, and reliability functions $f(x), f(y), F(x), F(y)$. $S(x) = 1 - F(x)$ and $F(y)$

1. Likelihood ratio order ($X \leq_{LR} Y$) if $\frac{f_{X_w}(x)}{f_{Y_w}(x)}$ decreases in x
2. Stochastic order ($X \leq_{ST} Y$) if $F_{X_w}(x) \geq F_{Y_w}(x)$ for all x
3. Hazard rate order ($X \leq_{HR} Y$) if $h_{X_w}(x) \geq h_{Y_w}(x)$ for all x
4. Mean residual life order ($X \leq_{MRL} Y$) if $MRL_{X_w}(x) \geq MRL_{Y_w}(x)$ for all x

Prove that the weighted Xrama distribution gives the strongest ordering (likelihood ratio ordering) Suppose X and Y are independent random variables with probability distribution functions $f_{w_x}(x; \alpha, \theta)$ and $f_{w_y}(x; \beta, \lambda)$. If $\alpha < \beta$ and $\theta < \lambda$, then.

$$\Lambda = \frac{f_{w_x}(x; \alpha, \theta)}{f_{w_y}(x; \beta, \lambda)}$$

$$\Lambda = \frac{\left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right)}{\left(\frac{x^\beta \lambda^{\beta+4} (\lambda^3 + 6x^3 + 12) e^{-\lambda x}}{\lambda^6 \beta! + 6(\beta+3)! + \lambda^3 12 \beta!} \right)}$$

$$\Lambda = \left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right) \times \left(\frac{\lambda^6 \beta! + 6(\beta+3)! + \lambda^3 12 \beta!}{x^\beta \lambda^{\beta+4} (\lambda^3 + 6x^3 + 12) e^{-\lambda x}} \right)$$

$$\Lambda = \left(\frac{x^\alpha \theta^{\alpha+4} (\theta^3 + 6x^3 + 12)}{x^\beta \lambda^{\beta+4} (\lambda^3 + 6x^3 + 12)} \right) \times \left(\frac{\lambda^6 \beta! + 6(\beta+3)! + \lambda^3 12 \beta!}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right) e^{-(\theta-\lambda)x}$$

$$\Lambda = \left(\frac{\theta^{\alpha+4} (x^\alpha (\theta^3 + 6x^3 + 12))}{\lambda^{\beta+4} (x^\beta (\lambda^3 + 6x^3 + 12))} \right) \times \left(\frac{\lambda^6 \beta! + 6(\beta+3)! + \lambda^3 12 \beta!}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right) e^{-(\theta-\lambda)x}$$

Therefore

$$\log [\Lambda] = \log \left(\left(\frac{\theta^{\alpha+4} (x^\alpha (\theta^3 + 6x^3 + 12))}{\lambda^{\beta+4} (x^\beta (\lambda^3 + 6x^3 + 12))} \right) \times \left(\frac{\lambda^6 \beta! + 6(\beta+3)! + \lambda^3 12 \beta!}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right) e^{-(\theta-\lambda)x} \right)$$

differentiate with respect to x , we get

$$\frac{\partial \log [\Lambda]}{\partial x} = \left(\frac{\alpha x^{\alpha-1} \theta^3 + 6(\alpha+3) x^{\alpha+2} + 12 x^{\alpha-1}}{x^\alpha \theta^3 + 6x^{\alpha+3} + 12 x^\alpha} \right) - \left(\frac{\beta x^{\beta-1} \lambda^3 + 6(\beta+3) x^{\beta+2} + 12 x^{\beta-1}}{x^\beta \lambda^3 + 6x^{\beta+3} + 12 x^\beta} \right) + (\lambda - \theta) = 0$$

Hence $\frac{\partial \log [\Lambda]}{\partial x} < 0$ if $\alpha < \beta$ and $\theta < \lambda$

Entropies

In this part, we used the weighted Xrama distribution to calculate Shannon, Renyi, and Tsallis entropies.

It is commonly known that entropy and information can be used to measure uncertainty or the randomness of probability distributions. It is used in a variety of disciplines, including engineering, finance, information theory, and biomedicine. The entropy functionals for the probability distribution were developed using a variational concept of uncertainty.

Shannon Entropy

The Shannon entropy of the random variable X that defines the weighted Xrama distribution





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$$s_{\lambda} = - \int_0^{\infty} f(x) \log(f(x)) dx; \lambda > 0, \lambda \neq 1$$

$$s_{\lambda} = - \int_0^{\infty} f_w(x; \theta, \alpha) \log(f_w(x; \theta, \alpha)) dx$$

$$s_{\lambda} = - \int_0^{\infty} \left(\frac{x^{\alpha} \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) \times \log \left(\frac{x^{\alpha} \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right) dx \quad (15)$$

Renyi Entropy

Entropy is described as a random variable. X represents the variation of the uncertainty. Engineering, statistical mechanics, finance, information theory, biology, and economics are among the domains where it is applied. The entropy is the Renyi of order, which is defined as

$$R_{\lambda} = \frac{1}{1-\lambda} \log \int_0^{\infty} [f(x)]^{\lambda} dx; \lambda > 0, \lambda \neq 1$$

$$R_{\lambda} = \frac{1}{1-\lambda} \log \int_0^{\infty} [f_w(x; \theta, \alpha)]^{\lambda} dx$$

$$R_{\lambda} = \frac{1}{1-\lambda} \log \int_0^{\infty} \left(\frac{x^{\alpha} \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{\lambda} dx$$

$$R_{\lambda} = \frac{1}{1-\lambda} \log \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{\lambda} \int_0^{\infty} x^{\alpha \lambda} (\theta^3 + 6x^3 + 12)^{\lambda} e^{-\lambda \theta x} dx \quad (16)$$

Then, utilizing the following binomial series expansion in equation (16) and simplified this, we obtain:

$$R_{\lambda} = \frac{1}{1-\lambda} \log \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{\lambda} \sum_{i=0}^{\lambda} \sum_{j=0}^{\lambda} \binom{\lambda}{i} \binom{i}{j} \theta^{3(\lambda-i)} 6^{(i-j)} 12^j \int_0^{\infty} x^{\lambda \alpha + 3(i-j)} e^{-\lambda \theta x} dx$$

Using the gamma function

$$R_{\lambda} = \frac{1}{1-\lambda} \log \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{\lambda} \sum_{i=0}^{\lambda} \sum_{j=0}^{\lambda} \binom{\lambda}{i} \binom{i}{j} \theta^{3(\lambda-i)} 6^{(i-j)} 12^j \left(\frac{(\lambda \alpha + 3(i-j) + 1)}{(\lambda \theta)^{(\lambda \alpha + 3(i-j) + 1)}} \right) \quad (17)$$

Tsallis Entropy

Tsallis initiated the Boltzmann-Gibbs (B-G) statistical properties, which have gained a lot of attention. This generalization of (B-G) statistics was initially proposed by introducing the mathematical formulation of Tsallis entropy (Tsallis, 1988) for continuous random variables, which is defined as

$$T_{\lambda} = \frac{1}{1-\lambda} \left[1 - \int_0^{\infty} [f(x)]^{\lambda} dx \right]; \lambda > 0, \lambda \neq 1$$

$$T_{\lambda} = \frac{1}{1-\lambda} \left[\int_0^{\infty} \left(\frac{x^{\alpha} \theta^{\alpha+4} (\theta^3 + 6x^3 + 12) e^{-\theta x}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{\lambda} dx \right]$$

$$T_{\lambda} = \frac{1}{1-\lambda} \left[1 - \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!} \right)^{\lambda} \int_0^{\infty} x^{\alpha \lambda} (\theta^3 + 6x^3 + 12)^{\lambda} e^{-\lambda \theta x} dx \right]$$

Using binomial expansion, we get





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$$T_{\lambda} = \frac{1}{1-\lambda} \left[1 - \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right)^{\lambda} \sum_{i=0}^{\lambda} \sum_{j=0}^{\lambda} \binom{\lambda}{i} \binom{\lambda}{j} \theta^{3(\lambda-i)} 6^{(i-j)} 12^j \int_0^{\infty} x^{\lambda \alpha + 3(i-j)} e^{-\lambda \theta x} dx \right] \quad (18)$$

Using integration of gamma function in equation (18), we get

$$T_{\lambda} = \frac{1}{1-\lambda} \left[1 - \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right)^{\lambda} \sum_{i=0}^{\lambda} \sum_{j=0}^{\lambda} \binom{\lambda}{i} \binom{\lambda}{j} \theta^{3(\lambda-i)} 6^{(i-j)} 12^j \left(\frac{(\lambda \alpha + 3(i-j) + 1)}{(\lambda \theta)^{(\lambda \alpha + 3(i-j) + 1)}} \right) \right] \quad (19)$$

Estimations of Parameter

This section provides the MLE and Fisher's information matrix for the WXD.

MLE and Fisher's Information Matrix

Assume $X_{(1)}, X_{(2)}, X_{(3)}, \dots, X_{(n)}$ is a random sample of size n from the weighted Xrama distribution with parameter and the likelihood function, which is defined as

$$L(x; \theta, \alpha) = \prod_{i=1}^n f_w(x_i; \theta, \alpha)$$

$$L(x; \theta, \alpha) = \prod_{i=1}^n \left(\frac{x_i^{\alpha} \theta^{\alpha+4} (\theta^3 + 6x_i^3 + 12) e^{-\theta x_i}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right)$$

$$= \left(\frac{\theta^{\alpha+4}}{\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!} \right)^n \prod_{i=1}^n x_i^{\alpha} (\theta^3 + 6x_i^3 + 12) e^{-\theta x_i}$$

Then, the log-likelihood function is

$$\log L = n \log \theta^{\alpha+4} - n \log(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!) + \sum_{i=1}^n \log x_i^{\alpha} (\theta^3 + 6x_i^3 + 12) - \theta \sum_{i=1}^n x_i \quad (20)$$

Deriving (20) partially with respect to θ, α and we have.

$$\frac{\partial \log L}{\partial \theta} = \frac{n(\alpha+4)}{\theta} - n \left(\frac{6\theta^5 \alpha! + 3\theta^2 12 \alpha!}{(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!)} \right) - \sum_{i=1}^n x_i = 0 \quad (21)$$

$$\frac{\partial \log L}{\partial \alpha} = n \log(\theta) - \left(\frac{\theta^6 \psi(\alpha) + 6\psi(\alpha+3) + \theta^3 12 \psi(\alpha)}{(\theta^6 \alpha! + 6(\alpha+3)! + \theta^3 12 \alpha!)} \right) + \sum_{i=1}^n \log x_i = 0 \quad (22)$$

Where ψ is the digamma function.

Equations (21) and (22) provide the MLE of the parameters for the WXD. However, because the problem cannot be solved analytically, we solved it numerically using R programming and a data collection.

We apply asymptotic normality results to get the confidence interval. If $\hat{\lambda} = (\hat{\theta}, \hat{\alpha})$ represents the MLE of $\lambda = (\theta, \alpha)$, we can state the following results: $\sqrt{n}(\hat{\lambda} - \lambda) \rightarrow N_2(0, I^{-1}(\lambda))$

$I(\lambda)$ is Fisher's information matrix. i.e.,





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$$I(\lambda) = \frac{1}{n} \begin{pmatrix} E \left[\frac{\partial^2 \log L}{\partial \theta^2} \right] & E \left[\frac{\partial^2 \log L}{\partial \theta \partial \alpha} \right] \\ E \left[\frac{\partial \log L}{\partial \alpha \partial \theta} \right] & E \left[\frac{\partial^2 \log L}{\partial \alpha^2} \right] \end{pmatrix}$$

$$E \left[\frac{\partial^2 \log L}{\partial \theta^2} \right] = \frac{-n(\alpha + 4)!}{\theta^2} + n \left(\frac{(\theta^2 \alpha! + 6(\alpha + 3)! + \theta^3)(30\theta^4 \alpha! + 36\theta \alpha!) - (6\theta^5 \alpha! + 36\theta^2 \alpha!)^2}{(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)^2} \right)$$

$$E \left[\frac{\partial \log L}{\partial \alpha^2} \right] = n \left(\frac{(\theta^6 \Psi'(\alpha) + 6\Psi(\alpha + 3) + \Psi'(\alpha))(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!) - (\theta^6 \Psi(\alpha) + 6\Psi(\alpha + 3) + \theta^3 12 \Psi(\alpha))^2}{(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)^2} \right)$$

$$E \left[\frac{\partial^2 \log L}{\partial \theta \partial \alpha} \right] = \frac{n}{\theta} + n \left(\frac{(6\theta^5 \Psi(\alpha) + 36\theta^2 \Psi(\alpha))(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!) - (6\theta^5 \alpha! + 36\theta^2 \alpha!)(\theta^6 \Psi(\alpha) + 6\Psi(\alpha + 3) + \theta^3 12 \Psi(\alpha))}{(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)^2} \right)$$

$$E \left[\frac{\partial \log L}{\partial \alpha \partial \theta} \right] = \frac{n}{\theta} + n \left(\frac{(6\theta^5 \Psi(\alpha) + 36\theta^2 \Psi(\alpha))(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!) - (6\theta^5 \alpha! + 36\theta^2 \alpha!)(\theta^6 \Psi(\alpha) + 6\Psi(\alpha + 3) + \theta^3 12 \Psi(\alpha))}{(\theta^6 \alpha! + 6(\alpha + 3)! + \theta^3 12 \alpha!)^2} \right)$$

The first order derivative of the digamma function is $\Psi(\cdot)'$. Because λ is unknown, we estimate $I^{-1}(\lambda)$ by $I^{-1}(\hat{\lambda})$, which can be used to obtain an asymptotic confidence interval for θ, α .

Applications

Data set 1: The dataset on the remission periods (in months) of 36 bladder cancer patients described in [9] and provided by

0.08, 0.2, 0.4, 0.5, 0.51, 0.81, 0.87, 0.9, 1.05, 1.19, 1.26, 1.35, 1.4, 1.46, 1.76, 2.02, 2.02, 2.07, 2.09, 2.23, 2.26, 2.46, 2.54, 2.62, 2.64, 2.69, 2.69, 2.75, 2.83, 2.87, 3.02, 3.02, 3.25, 3.31, 3.36, 3.36.

Data set 2: This data set includes the life expectancy (in years) of 40 blood cancer (leukemia) patients from one of Saudi Arabia's Ministry of Health facilities, as described in [1]. The actual data are:

0.315, 0.496, 0.616, 1.145, 1.208, 1.263, 1.414, 2.025, 2.036, 2.162, 2.211, 2.370, 2.532, 2.693, 2.805, 2.910, 2.912, 3.192, 3.263, 3.348, 3.348, 3.427, 3.499, 3.534, 3.767, 3.751, 3.858, 3.986, 4.049, 4.244, 4.323, 4.381, 4.392, 4.397, 4.647, 4.753, 4.929, 4.973, 5.074, 5.381.

To compare to the goodness of fit of the fitted distribution, the following criteria: Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), Akaike Information Criteria Corrected (AICC) and $-2\log L$.

AIC, BIC, AICC and $-2\log L$ can be evaluated by using the formula as follows.

$$AIC = 2K - 2\log L, \quad BIC = k \log n - 2\log L \text{ and } AICC = AIC + \frac{2k(k+1)}{(n-k-1)}$$

Where, k =number of parameters, n sample size and $-2\log L$ is the maximized value of loglikelihood function.

Tables 1 and 2 clearly show that the weighted Xrama distribution has lower AIC, BIC, AICC, $-2\log L$, and values than the Xrama, power Akash, Lindley, and Akash distributions, indicating that the WXD fits better. As a result, the WXD outperforms the other distributions in terms of fit.





CONCLUSION

This paper proposes and discusses a weighted version of the Xrama distribution known as the WXD. Its important statistical features, such as moments and their associated measures, reliability function, hazard rate, reverse hazard function, and mean residual life function, are investigated. The suggested distribution's parameters are determined using the maximum likelihood technique. The use of statistical distributions in medical research is vital and can have a substantial impact on the health of the general public, especially cancer patients. Thus, the applications of this distribution to certain real-life cancer data sets that reflect the survival of some cancer patients demonstrate the applicability of this distribution. Furthermore, the resulting distribution is applied to two real-life cancer data sets and contrasted with other well-known distributions. The results reveal that the WXD provides a better fit than other well-known distributions.

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Table.1:MLEs AIC, BIC, AICC, and -2log L of the fitted distribution for the given data set1

Distribution	MLEs	-2 log L	AIC	BIC	AICC
Weighted Xrama distribution	$\hat{\theta} = 1.9931313 (1.9931313)$ $\hat{\alpha} = 1.2714682 (0.5280264)$	104.4686	108.4686	111.6357	108.8322
Xramadistribution	$\hat{\theta} = 1.30968439 (0.09193344)$	114.5201	116.5201	118.1036	116.8837
Power Akash distribution	$\hat{\theta} = 1.0506473 (0.1221529)$ $\hat{\alpha} = 1.1400227 (0.1160769)$	108.9252	112.9252	116.0922	113.2888
Lindley Distribution	$\hat{\theta} = 0.80158184 (0.09952089)$	113.3976	115.3976	116.9811	115.7607
Akash Distribution	$\hat{\theta} = 1.140241 (0.106786)$	110.4578	112.4578	114.0413	112.8214

Table.2:MLEs AIC, BIC, AICC, and -2log L of the fitted distribution for the given data set 2

Distribution	MLEs	-2 log L	AIC	BIC	AICC
Weighted Xrama distribution	$\hat{\theta} = 1.607292 (0.260660)$ $\hat{\alpha} = 1.649207 (0.723085)$	140.9343	144.9343	148.3121	145.2586
Xrama distribution	$\hat{\theta} = 1.00821003 (0.06931274)$	151.276	153.276	154.9649	153.6003
Power Akash distribution	$\hat{\theta} = 0.88137978 (0.10407849)$ $\hat{\alpha} = 0.89875032 (0.08503451)$	151.3368	155.3368	158.7146	155.6611
Lindley Distribution	$\hat{\theta} = 0.52692132 (0.06074766)$	160.5012	162.5012	164.1943	162.8255
Akash Distribution	$\hat{\theta} = 0.80063395 (0.07022243)$	152.6894	154.6894	156.3783	155.0137

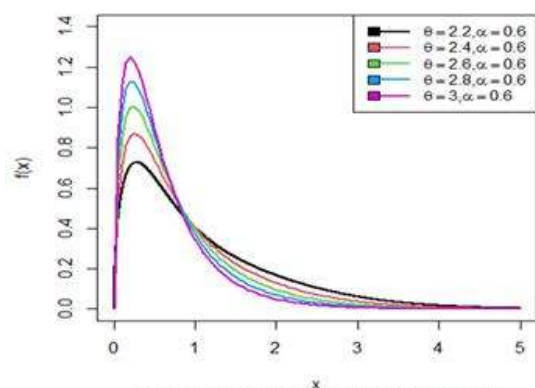


Figure.1:Pdf plot of weighted Xrama distribution

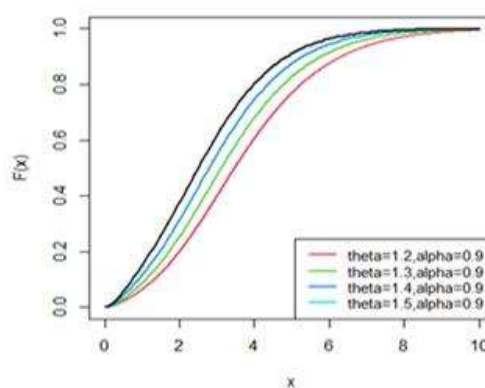


Figure 2 Cdf plot of weighted Xrama distribution

Figure.1:Pdf Plot of Weighted Xrama Distribution

Figure.2:Cdf Plot of Weighted Xrama Distribution



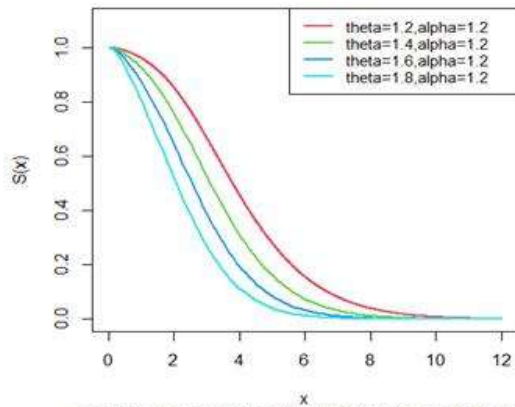


Figure.3 survival function of the Weighted Xrama distribution

Figure.3: Survival Function of the Weighted Xrama Distribution

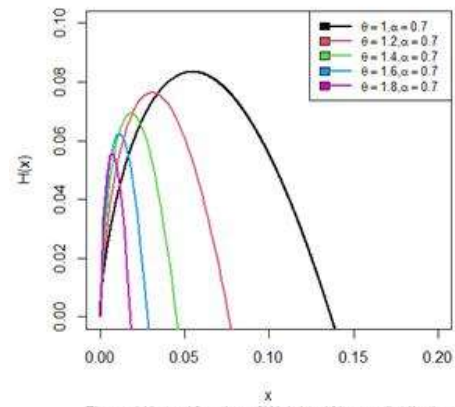


Figure.4 Hazard function of Weighted Xrama distribution

Figure.4:Hazard Function of the Weighted Xrama Distribution





Internal Audit Procedure for Regulatory Compliance Issues

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ABSTRACT

Internal audit procedures have evolved significantly, adapting to the complexities of global regulations and business practices. Initially focused on financial oversight and fraud prevention, audits expanded with regulatory advancements, such as the FDA's guidelines and Good Manufacturing Practices (GMP). The rise of frameworks like the Sarbanes-Oxley Act (SOX) further integrated risk management into audit practices, emphasizing compliance with stringent regulatory standards. In the pharmaceutical industry, internal audits now encompass a wide range of compliance requirements, including GMP, FDA regulations, pricing transparency laws, and environmental standards. The analysis of internal audit findings from 20 companies reveals significant challenges in regulatory compliance, internal controls, and operational risks. Weaknesses in financial reporting were the most frequent issue, reported by 12 companies, often leading to inaccuracies, scrutiny, and investor distrust. Regulatory hurdles in drug approvals and pricing transparency were also prevalent, impacting 11 companies. Additional concerns, such as anti-corruption compliance, product liability lawsuits, and post-merger integration, highlight the complexities of global operations. Pharmaceutical companies must enhance internal audits by adopting advanced tools like data analytics, real-time monitoring, and risk-based assessments. Strengthened internal controls and compliance frameworks are critical to mitigating financial and reputational risks, ensuring operational stability, and maintaining competitiveness in a highly regulated industry.

Keywords: Internal audits; Regulatory compliance; Pharmaceutical industry; Financial reporting; Global standards.





INTRODUCTION

Internal audits are essential in the pharmaceutical industry, assisting companies in ensuring compliance with regulatory standards, identifying potential risks, and upholding product quality and safety. As pharmaceutical companies navigate increasingly complex regulations and dynamic market conditions, the importance of effective internal audit processes becomes paramount. [1,4,5]

Regulations and standards of internal audits

The revised Global Internal Audit Standards are set to take effect on January 9, 2024, and will remain in place until January 9, 2025. Internal audit functions may already be incorporating these Standards into their operations. These Standards serve as a comprehensive framework for internal auditing professionals worldwide, offering guidance that supports the assessment and enhancement of internal audit quality. The International Internal Audit Standards Board, operating under the oversight of the IPPF Oversight Council, develops these Standards through a rigorous due process. [6] Currently, internal audits are a key requirement for maintaining compliance with a range of accepted standards, including ISO 9001:2000, ISO 14001:2015, and ISO 13485.[2] These audits serve as a critical mechanism for evaluating and enhancing quality within organizations. A similar principle is reflected in the regulations imposed by major global authorities, such as the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA). For example, the evaluation of quality standards in the pharmaceutical sector, including blood and blood components, is governed by cGMP regulations (21 CFR Parts 210-211 & 206). In the European Union, public-interest entities are required to comply with Regulation (EU) No 537/2014, a statutory audit framework passed by the European Parliament and Council. This regulation, part of a broader legislative structure under Directive 2006/43/EC, aims to strengthen audit quality and independence by limiting non-audit services, defining the role of national audit oversight bodies, and mandating auditor rotation. The Committee of European Auditing Oversight Bodies oversees adherence to these standards, ensuring consistency across EU member states. [3,4,5] In India, the Institute of Chartered Accountants of India (ICAI) and the Institute of Cost Accountants of India (ICMAI) have issued guidelines for conducting internal audits in the pharmaceutical industry. These guidelines emphasize best practices in areas such as procurement, production, and inventory management. Internal audits are also essential for ensuring compliance with ISO 9001 standards, the Drugs and Cosmetics Act, 1940, and its associated Rules, 1945, which emphasize quality control and documentation. Additionally, adherence to the National Pharmaceuticals Pricing Policy (NPPP), Good Laboratory Practices (GLP), and Good Manufacturing Practices (GMP) is critical, with internal audits playing a pivotal role in confirming compliance with these regulations. [5,7] Global regulatory authorities across the pharmaceutical and medical device sectors share a common expectation regarding the role of internal audits. For example, the UK's Medicines and Healthcare Products Regulatory Agency (MHRA) emphasizes the need for robust internal quality systems and regular audits to ensure compliance with Good Manufacturing Practices (GMP). Similarly, Health Canada incorporates internal audits into its compliance framework, expecting companies to perform thorough audits that assess regulatory adherence and promote continuous quality improvement. In Japan, the Pharmaceuticals and Medical Devices Agency (PMDA) mandates internal audits focused on compliance with GMP and Good Clinical Practices (GCP), requiring organizations to systematically evaluate their processes and take corrective actions based on audit findings.[5] Across these regions, the common thread is the critical role of internal audits in maintaining high standards of quality, transparency, and accountability, fostering continuous improvement in the pharmaceutical and medical device industries.

MATERIALS AND METHODS

Definition of Internal Audit

An internal audit is an independent and objective review of an organization's financial and operational activities. Conducted by the company's own staff, internal audits evaluate the effectiveness of internal controls, procedures, and processes. They also assess compliance with relevant laws, regulations, and company policies. The main goal of an internal audit is to offer management an unbiased assessment of the organization's risk and control environment.



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These audits are performed regularly, and their findings are reported to senior management and the board of directors.[5]

Internal audit procedure

The ISO standard mandates that organizations develop an internal audit procedure.

This Internal Audit Procedure should encompass the following elements:

- Internal Audit Schedule: Identify who is responsible for creating the schedule, determine the frequency of audits, and outline the scope of each audit.
- Auditor: Specify who will carry out the internal audits and describe how impartiality and objectivity in the audit process will be maintained.
- Audit Report: Detail the process for reporting findings.
- Audit Review: Clarify that management is responsible for reviewing the internal audit report.
- Retention of Reports and Evidence: Explain how reports and relevant evidence will be retained.[8]

Planning the Audit

- Review the audit scope and identify relevant procedures and documents.
- Identify the staff and stakeholders who need to be present and invite them to participate.
- Examine the procedures and other documents related to the audit scope.
- Determine the evidence required to demonstrate compliance with the procedures and standards.
- Develop an internal audit checklist that includes key questions to ask and evidence to examine.
- Examine prior internal and external audit reports to pinpoint any necessary corrective actions.

Conducting the Audit

- Ask the auditee to explain their processes and how records are maintained to demonstrate compliance.
- Look for objective evidence of compliance, usually found in recorded form.
- If you discover any issues, ensure the auditee is informed and understands them.
- Focus on fact-finding rather than fault-finding; the goal is to gather facts, not to point out faults.
- Remain objective; your personal opinions should not influence the audit.

Writing the Audit Report

- Document the objective evidence observed during the audit.
- Record any non-conformances and suggestions for improvement.
- Discuss the system itself rather than the roles of individuals within it. [8]

A review of internal audit reports was conducted based on the annual reports of 20 companies. This evaluation sought to analyse the effectiveness, coverage, and key outcomes of their internal audit activities. By reviewing the data presented in these reports, the study aimed to gain insights into how companies are managing compliance, risk, and quality control through their internal audit functions.

RESULTS

The review also identified common practices, challenges, and opportunities for improvement, offering a broader perspective on the current state of internal auditing across various industries in table: 1 The comprehensive analysis of compliance challenges in the pharmaceutical industry reveals a complex landscape of regulatory and operational risks. Categorization involves grouping similar issues based on their characteristics, nature, or impact. For instance, financial reporting weaknesses relate to inaccuracies in statements; anti-corruption involves breaches of ethical laws; product safety concerns involve defects leading to recalls. Supply chain disruptions focus on compliance and logistical issues, while regulatory challenges involve meeting approval requirements. This systematic grouping aids in better understanding and addressing each problem area effectively. The categories and frequencies are listed in table :2. The table outlines ten categories of audit issues and their frequencies. Financial reporting and internal



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control weaknesses (12 occurrences) and Regulatory compliance and approval challenges (11 occurrences) are the most frequent. Product safety, quality, and recalls, Litigation and legal disputes, and Mergers, acquisitions, and integration challenges each appear 4 times. Categories like Anti-corruption and anti-bribery compliance, Global supply chain disruptions, Environmental compliance and sustainability issues, and Operational inefficiencies in clinical trials each have 3 occurrences, while Ethical pricing and market practices are noted twice. This distribution highlights critical areas for improvement.

DISCUSSION

Pharmaceutical companies encounter a variety of complex challenges that require continuous attention to compliance and internal controls. One major issue is adjusting to evolving regulations, especially those related to drug approvals and pricing, which can result in delays and increased operational costs. Ensuring compliance with global supply chain standards and environmental sustainability requirements is equally crucial, as these regulations vary across regions. The most common issue identified, however, is internal control weaknesses in financial reporting, which 12 of companies' face. These weaknesses can lead to inaccurate financial statements, regulatory scrutiny, and loss of investor confidence, highlighting the need for stronger oversight mechanisms. In addition to financial reporting challenges, pharmaceutical companies must address regulatory hurdles in drug approvals and clinical trial data, which were noted in 11 of cases. Problems such as incomplete trial data or inadequate documentation can cause delays in market access and harm a company's reputation. Other significant concerns include compliance with anti-corruption laws, product liability litigation, and antitrust regulations, all of which can result in serious legal and financial repercussions.

Case Studies**Case Study 1**

Viatis Inc., a global healthcare company formed through the merger of Mylan and Pfizer's Upjohn business, faced significant internal audit challenges, as outlined in its 2023 Form 10-K. The company identified key weaknesses in its internal controls, particularly over financial reporting, which raised concerns about the reliability of its financial reporting processes. One major issue was the difficulty in correcting errors in previously issued financial statements. Viatis also acknowledged potential risks to its compliance with Section 404 of the Sarbanes-Oxley Act, which requires management to assess and report on the effectiveness of internal controls. The audit findings reveal that Operational Risks and Manufacturing Compliance occurring twice, highlighting challenges in maintaining compliance with manufacturing standards and regulatory requirements. Internal Controls Over Financial Reporting, Cyber security and Data Integrity, and Sustainability and Compliance were identified once each, focusing on financial controls, data security, and adherence to environmental and sustainability standards. These findings emphasize the need for robust systems and processes to ensure regulatory compliance, operational efficiency, and data security.

Case study 2

In 2012, GlaxoSmithKline (GSK) faced significant internal audit issues that led to a Corporate Integrity Agreement (CIA) with the U.S. Department of Health and Human Services' Office of Inspector General (OIG). The problems primarily arose from improper marketing practices and non-compliance at GSK's Cidra, Puerto Rico facility, where drugs were manufactured under questionable standards. Internal audits revealed that GSK's compliance program was inadequate, with significant gaps in its implementation and monitoring, leading to unauthorized interactions with healthcare professionals. Additionally, GSK failed to report violations such as potential kickbacks and lacked a robust whistleblower policy. Furthermore, senior management's oversight was ineffective, as the Compliance Officer did not have direct access to the board, limiting their ability to enforce compliance. The Compliance Violations in Speaker Programs for GSK involved unauthorized promotion of off-label product uses, insufficient oversight of speaker activities, and conflicts of interest arising from excessive financial incentives to healthcare professional. As a result, GSK was required to implement reforms, including strengthening its compliance program, enhancing training



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on federal regulations, and conducting regular audits. These issues serve as a reminder of the importance of active enforcement and monitoring of compliance frameworks within regulated industries.

Case study 3

Organon & Co., a global healthcare company focused on women's health, faced significant internal audit challenges as outlined in its 2022 Annual Report. Despite its success as a spin-off from Merck in 2021, the company encountered weaknesses in regulatory compliance, particularly in manufacturing processes that failed to consistently meet required safety and quality standards. The audits also revealed deficiencies in documentation practices, risking non-compliance with FDA regulations. Additionally, internal controls were inadequate, with poor segregation of duties and insufficient risk assessment procedures, exposing the company to potential financial and reputational risks. The internal audit found limited engagement from senior management on compliance issues, and the reporting structure for concerns was unclear. The most common issue is Management's Assessment of Internal Controls, highlighting the need for stronger evaluations of control systems. Compliance with Filing Requirements and Revenue Recognition Practices were moderately frequent, focusing on meeting regulatory deadlines and accurate reporting of revenue. Operational Risks and Financial Performance (2022) reflect concerns about business processes and financial outcomes for the year. Lastly, Global Operations had the fewest issues, pointing to fewer challenges in international activities. The chart emphasizes key areas requiring attention to improve compliance and efficiency.

Case study 4

Pfizer is a global pharmaceutical giant founded in 1849, headquartered in New York City, with annual revenues around \$71.8 billion and operations in over 125 countries. The case study on internal audit issues at Pfizer reveals several critical areas of concern that impact the company's operational integrity and regulatory compliance. Key issues identified include gaps in regulatory compliance, which were noted multiple times, indicating potential risks in adherence to industry standards. Additionally, there is a misalignment in the structure of the Board of Directors' committees, affecting effective governance and decision-making processes. The audit also highlights a dependency on certain key product lines for revenue, which poses financial risks if these products encounter market challenges. Furthermore, inefficiencies in research and development processes were observed, potentially hindering innovation. Challenges related to mergers and acquisitions were also noted, particularly regarding integration post-acquisition. Lastly, there are concerns about compliance with Environmental, Social, and Governance (ESG) principles, which are increasingly vital in the pharmaceutical industry. Addressing these issues is essential for Pfizer to enhance its internal audit effectiveness and maintain its competitive edge in the market.

CONCLUSIONS

The analysis highlights Financial Reporting and Internal Control Weaknesses (12 occurrences) and Regulatory Compliance and Approval Challenges (11 occurrences) as the most frequent and critical issues in the pharmaceutical industry. Financial reporting weaknesses undermine the reliability of financial statements and expose companies to regulatory and reputational risks, making robust internal controls essential. Regulatory compliance challenges, including difficulties in navigating global approval frameworks, often lead to delays in product launches and supply chain disruptions, affecting operational efficiency and competitiveness. Addressing these two areas should be prioritized to strengthen financial oversight, enhance compliance processes, and mitigate risks, thereby fostering greater operational resilience and trust within the industry. The case studies underscore the critical need for pharmaceutical companies to strengthen internal controls over financial reporting and enhance regulatory compliance frameworks to address recurring challenges. Prioritizing these areas is essential for maintaining operational integrity, mitigating risks, and ensuring long-term sustainability.





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Conflict of interest

None to declare

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Table.1: List of 20 Companies With Their Internal Audit And Compliance Issues

Sl. No	Company	Internal Audit Compliance Issues
1	Teva Pharmaceutical (2019)	<ul style="list-style-type: none"> Internal control weaknesses in financial reporting process issues with compliance (FCPA) anti-corruption and anti-bribery laws (improper promotion and distribution of its pharmaceutical products through third parties.) agreed to pay approximately \$519 million to resolve FCPA violations
2	Johnson & Johnson (2019)	<ul style="list-style-type: none"> Internal control deficiencies in financial reporting, opioid litigation, talc litigation, product safety issues and recalls
3	Novartis (2019)	<ul style="list-style-type: none"> Compliance issues in anti-corruption and anti-bribery laws, agreed to pay \$346.7 million to resolve charges of bribery under the FCPA





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		<ul style="list-style-type: none"> • internal control weaknesses in financial reporting
4	AbbVie (2019)	<ul style="list-style-type: none"> • Weaknesses in internal controls over financial reporting, • issues related to Allergan acquisition
5	Pfizer (2020)	<ul style="list-style-type: none"> • Compliance issues with global supply chain (limited air freight capacity and port delays, affected the transportation of raw materials and finished products.) • internal control weaknesses and challenges in navigating regulatory framework with different countries
6	Cipla (2020)	<ul style="list-style-type: none"> • Challenges in meeting regulatory requirements related to compliance with c GMP. (Manufacturing deviations in sterilization protocols delayed exports of critical drugs to the U.S. market.)
7	Bristol-Myers Squibb (2021)	<ul style="list-style-type: none"> • Internal control weakness related to financial reporting and integration system (weaknesses emerged prominently in the context of its acquisition of Celgene Corporation)
8	Gilead sciences (2021)	<ul style="list-style-type: none"> • Internal control weakness related to financial reporting and integration system • Challenges in reconciling revenue tracking for drugs like Hepatitis C and HIV treatments due to system incompatibilities post-acquisitions.
9	Sanofi (2021)	<ul style="list-style-type: none"> • Struggled with justifying the premium pricing of Dupixent under new pricing transparency laws, delaying reimbursement approvals
10	Amgen (2021)	<ul style="list-style-type: none"> • Delays in launching biosimilars like Avastin due to differing clinical trial data requirements across regions, impacting competitive entry.
11	Bayer (2021)	<ul style="list-style-type: none"> • Issues related to environmental laws (improper waste disposal penalties at German plants) • product liability issues (Lawsuits over Roundup herbicide's alleged cancer risks)
12	Medtronic's (2021)	<ul style="list-style-type: none"> • Issues related to product safety and regulatory challenges • Recalls of heart devices due to battery malfunctions, with delays in reporting safety issues leading to regulatory penalties.
13	Viatis Inc. (2021)	<ul style="list-style-type: none"> • Internal control weakness related to financial reporting, • Delays in FDA approval of generic insulin Semglee due to challenges in aligning regulatory compliance systems post-merger
14	Mallinckrodt Pharmaceuticals (2022)	<ul style="list-style-type: none"> • Accused of price-fixing for Acthar Gel, exposing internal gaps in ethical pricing oversight and drawing lawsuits.
15	Regeneron Pharmaceuticals (2022)	<ul style="list-style-type: none"> • Compliance in its global operations internal control weakness over financial reporting
16	Vertex Pharmaceuticals (2022)	<ul style="list-style-type: none"> • weaknesses in its internal audit processes, which could result in undetected financial misstatements, • Regulatory scrutiny over clinical trial reporting for drug TrikaftaX
17	Stryker Corporation (2023)	<ul style="list-style-type: none"> • Compliance issues and internal control challenges in related to financial reporting (Errors in recognizing revenue after the acquisition of K2M, caused by weak financial data integration.)
18	Lupin Pharmaceuticals (2023)	<ul style="list-style-type: none"> • global supply chain issues. (Hurdles timely delivery of products to international markets.) • Challenges in meeting regulatory requirements related to drug approvals
19	Organon & Co. (2023)	<ul style="list-style-type: none"> • Internal audit weakness and compliance issues related to its global issues; • issues related to environmental laws (Issues with waste disposal





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		compliance at European facilities led to fines)
20	Abbot laboratories (2017)	<ul style="list-style-type: none"> • Internal control weakness related to financial reporting, • issues in compliance requirements (Delays in addressing FDA warnings about baby formula production contamination risks exposed lapses in safety)

Table.2: Categories of issues with frequency of occurrence

Sl. No	Category	Frequency
1	Financial reporting and internal control weaknesses	12
2	Regulatory compliance and approval challenges	11
3	Product safety, quality, and recalls	4
4	Litigation and legal disputes	4
5	Mergers, acquisitions, and integration challenges	4
6	Anti-corruption and anti-bribery compliance	3
7	Global supply chain disruptions	3
8	Environmental compliance and sustainability issues	3
9	Operational inefficiencies in clinical trials	3
10	Ethical pricing and market practices	2

Table.3: Audit Finding Issue and Number of Occurrences in Viatrix Inc. (2023)

SI No	Audit finding Issue	Occurrences
1	Internal Controls Over Financial Reporting	1
2	Operational Risks and Manufacturing Compliance	2
3	Cyber security and Data Integrity	1
4	Sustainability and Environmental Compliance	1

Table.4: Audit Finding Issue and Number of Occurrences in GlaxoSmithKline (2012)

SI no	Audit finding Issue	Occurrences
1	Deficiencies in Compliance Policies	2
2	Inadequate Documentation	1
3	Improper Promotional Activities	2
4	Weaknesses in Risk Mitigation Plans	1
5	Non-Adherence to Contractual Agreements	1
6	Compliance Violations in Speaker Programs	2

Table.5: Audit Finding Issue and Number of Occurrences in Organon & Co (2022)

SI no	Audit finding Issues	Occurrences
1	Management's Assessment of Internal Controls	1
2	Compliance with Filing Requirements	1
3	Revenue Recognition Practices	1



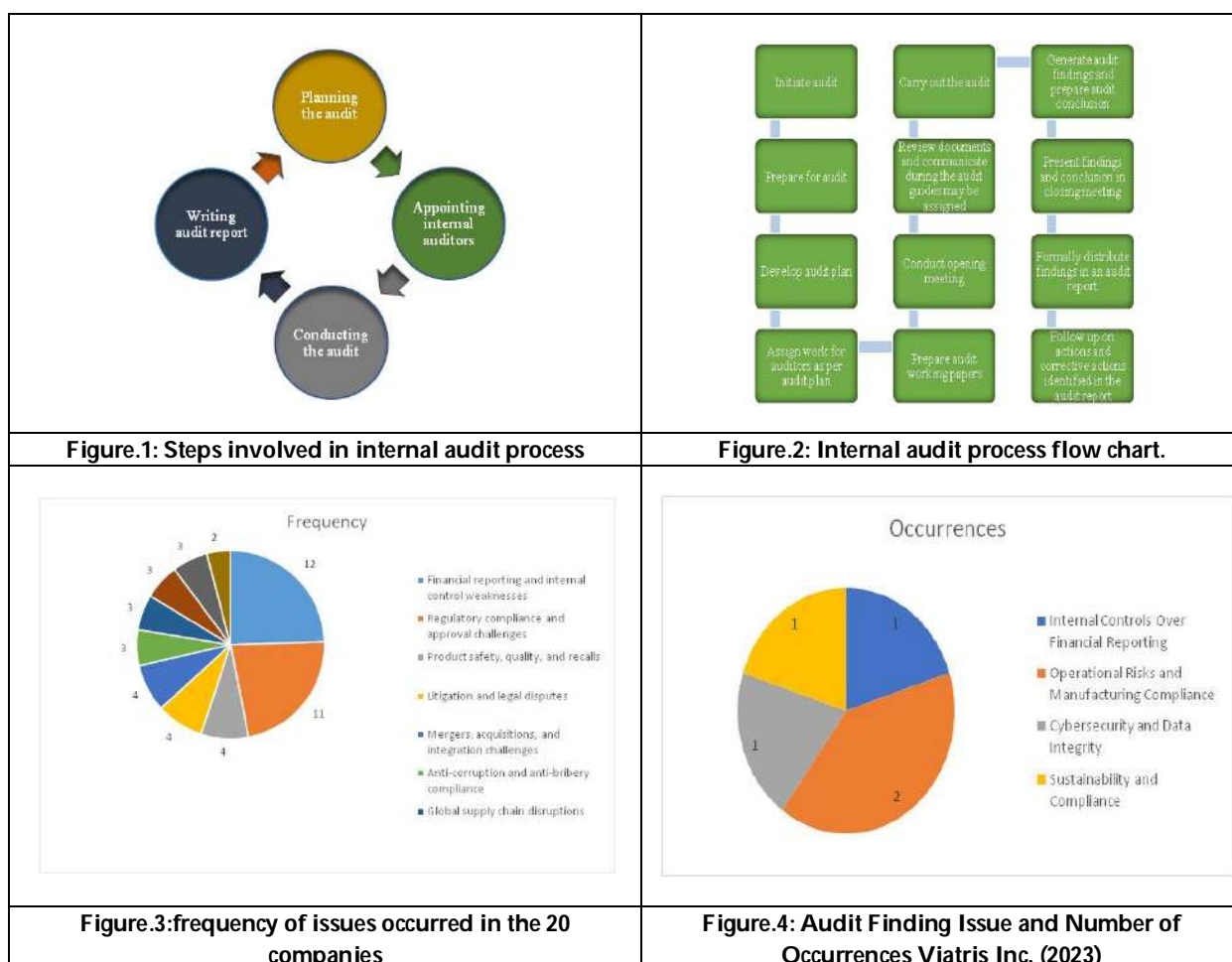


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4	Operational Risks	1
5	Financial Performance (2022)	1
6	Global Operations	1
7	Acquisitions and Licenses	4

Table.6: Audit Finding Issue and Number of Occurrences in Pfizer (2023)

SI.no	Audit finding Issue	Occurrences
1	Regulatory Compliance Gaps	5
2	Misalignment in Board Committee Structure	3
3	Dependency on Key Product Lines	4
4	Inefficiencies in R&D Processes	2
5	Challenges in Mergers and Acquisitions	3
6	Environmental, Social, and Governance (ESG) Compliance Issues	2



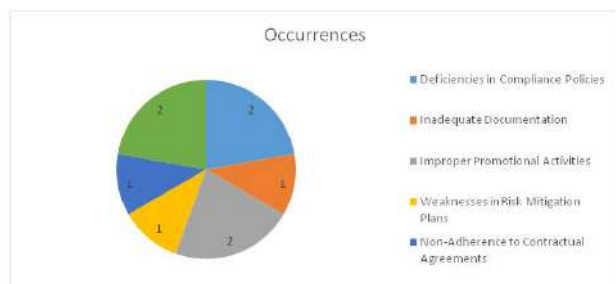


Figure.5: Audit Finding Issue and Number of Occurrences in GlaxoSmithKline (2012)

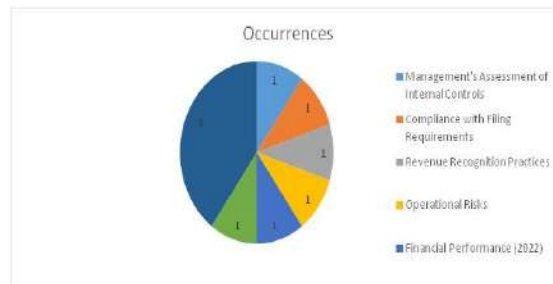


Figure.6: Audit Finding Issue and Number of Occurrences in Organon & Co (2022)

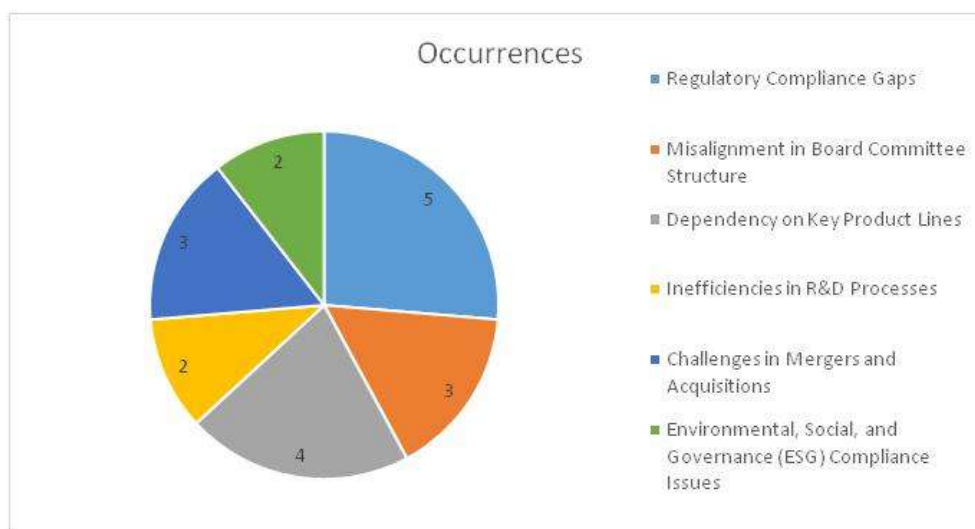


Figure.7: Audit Finding Issue and Number of Occurrences in Pfizer (2023)





Diuretic and Anti-Urolithiasis Activities of *Canna indica* Linn. Rhizome Extract in Wistar Rats

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ABSTRACT

Nephrolithiasis or Urolithiasis, commonly known as kidney or renal stone, is a highly prevalent clinical problem that affects about 20% of the human population. A majority of urinary stones are composed of phosphates, oxalates, cystine, and uric acid. The Freshly collected rhizomes were chopped into small pieces, shade dried for 3 weeks and powdered by using a mechanical grinder and were subjected to successive solvent extraction with ethanol and water by continuous hot percolation method using soxhlet apparatus. The buffer contains calcium chloride (5mmol/L) and sodium oxalate (7.5mmol/L) in Tris-HCl 0.05mol/l and NaCl 0.15mol/L (pH 6.5). Calcium chloride solution (9ml) was mixed with 1ml of herb extracts at different concentrations (10, 25, 50, 75 and 100mg/ml). The powdered Rhizome of *Canna indica* Linn. were extracted by ethanolic extraction technique using a soxhlet apparatus. Urolithiasis, mainly caused by calcium oxalate (CaOx) stones, involves crystal nucleation, growth, aggregation, and retention in the kidneys. Current treatments manage symptoms but do not directly inhibit CaOx crystallization, a key process in stone formation. Increased oxalate levels lead to oxidative stress, promoting CaOx crystal formation and kidney injury. *Canna indica* Linn.

Keywords: The Freshly collected rhizomes were chopped into small pieces, with ethanol and water by continuous hot percolation method using soxhlet apparatus.





INTRODUCTION

Nephrolithiasis or Urolithiasis, commonly known as kidney or renal stone, is a highly prevalent clinical problem that affects about 20% of the human population. A majority of urinary stones are composed of phosphates, oxalates, cystine, and uric acid. Almost 80% of these calculi are composed of calcium oxalate (CaOx) 1. Kidney stone formation is a complex process which is the outcome of several physio-chemical events such as super saturation, nucleation, crystal growth, aggregation, and retention 2. Stones develop from a wide variety of metabolic or environmental disturbances, including varying forms of hypercalciuria, hypocitraturia, undue urinary acidity, hyperuricosuria, hyperoxaluria and cystinuria 3, 4. In humans, calcium oxalate (CaOx) is the major component of urolithiasis, and CaOx stones constitute ~ 80% of all stones 5, 6. Diuretics play an important role in situations like hypercalciuria, oedema, acute and chronic renal failure, and cirrhosis of the liver, and act as an anti-hypertensive agent. Several diuretics like thiazides, furosemide, mannitol, and ethacrynic acid are used in practice. Urolithiasis needs both preventive and curative therapy. Currently, there are no satisfactory drugs in modern medicine, which can dissolve the stone and therefore physicians remain to be depending on alternative systems of medicine for better relief. The treatment choices are surgical procedures, diuretics, analgesics, alkalinization of urine, and in some cases, allopurinol treatment. Several herbal products have shown beneficial effects against urolithiasis and have diuretic activity, and these products found less side effects and toxicity comparatively 7, 8. *Canna indica* Linn., commonly known as Indian shot, or African arrowroot, is a plant species in the family Cannaceae. The major phytochemicals include alkaloids, carbohydrates, proteins, flavonoids, terpenoids, cardiac glycosides, steroids, tannins, saponins and phlobatannins 9. This plant possesses various medicinal properties like Anti-cancer, Anti-diarrheal effect, Anti-diabetic effect, Anti-inflammatory effect, Anti-nociceptive and anthelmintic effects, and Anti-bacterial effects. Ethnomedicinally, it is used in the treatment of kidney stones and is also used as a diuretic. Despite a long traditional use of *Canna indica* Linn. no systematic pharmacological work has ever been carried out on rhizomes for Kidney diseases 10, 11. Hence, the present study was carried out to evaluate the Diuretic and Anti-urolithiasis activities of *Canna indica* Linn. Rhizome extract in Wistar rats.

MATERIALS AND METHODS

Collection and Authentication

Fresh Rhizome of *Canna indica* Linn. was collected from Kottakkal, Malappuram District, Kerala, in the month of October 2019. The plant specimen was authenticated (Specimen No. 88489) by Dr. M. Pradeep, Assistant Professor and Head, Department of Botany, University of Calicut, Kerala, India. The specimen voucher was deposited in the Department.

Extraction and Phytochemical screening

The Freshly collected rhizomes were chopped into small pieces, shade dried for 3 weeks and powdered by using a mechanical grinder and were subjected to successive solvent extraction with ethanol and water by continuous hot percolation method using soxhlet apparatus. The crude samples were subjected to qualitative chemical tests for the detection of various plant constituents like alkaloids, flavonoids, terpenoids, alkaloids, glycosides etc 12.

Experimental Animals

Wistar rats (200-250g) and Swiss albino mice (25-30g) of either sex were used. Animals were housed in groups of five under standard laboratory conditions of temperature (25±20° C) and 12/12 h light/dark cycle. They were provided with standard pellets and tap water *ad libitum*. The study protocol was approved by the Institutional Animal Ethics Committee (IAEC) of CCSEA (Committee for Control and Supervision of Experiments on Animals)13.





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In-Vitro Study**Anti-Urolithiasis Activity****Nucleation Assay**

The buffer contains calcium chloride (5mmol/L) and sodium oxalate (7.5mmol/L) in Tris-HCl 0.05mol/l and NaCl 0.15mol/L (pH 6.5). Calcium chloride solution (9ml) was mixed with 1ml of herb extracts at different concentrations (10, 25, 50, 75 and 100mg/ml). Crystallization was initiated using 1250ml of sodium oxalate solution. The absorbance was read at 620nm every 30 minutes at 37°C. The rate of nucleation was estimated by comparing the induction time in the presence of extract with that of polyherbal drug Cystone as control 14.

$$\% \text{ inhibition of nucleation} = \frac{(\text{Absorbance of Control} - \text{Absorbance of Test})}{\text{Absorbance of Control}} \times 100$$

Aggregation assay

Calcium chloride and sodium oxalate solutions (50mmol/L) were equilibrated to 60°C in a water bath for 1hr and then cooled to 37°C overnight. The crystals formed were then harvested by centrifugation and evaporated at 37°C. Buffered crystal solution (0.8mg/ml) was prepared using Tris-HCl 0.05mol/L and NaCl 0.1 mol/L (pH 6.5). The percent inhibition of aggregation was calculated by comparing the turbidity in the presence of extract at different concentrations (10 –100mg/ml) with that obtained in the positive control (Cystone) and the negative control (distilled water), using the following formula 15.

$$\% \text{ inhibition of aggregation} = \frac{(1 - \text{Turbidity of Sample})}{\text{Turbidity of Negative control}} \times 100$$

In-Vivo Study**Evaluation of Diuretic Activity****Lipschitz method**

Wistar rats were selected and divided into five groups consisting of 6 rats in each group (n=6). Group I control, received orally sodium CMC (0.5%w/v), 10ml/kg. Group II, standard received orally 20mg/kg Furosemide. Group III and IV received orally 200mg/kg and 400mg/kg of ethanolic extract of *Canna indica* Linn. Rhizome respectively. After dosing, all the animals were placed in individual metabolic cages and urine was collected and measured at 1,2,3,4 and 5hr. Sodium and potassium concentration in urine samples was determined at 5th hour by standard biochemical analysis. Total urine volume and urinary concentration of Na⁺, K⁺, and Cl⁻ were measured 16.

Statistical Analysis

The results are expressed as mean± SD. The data was analysed by the Student T test. A value of P less than 0.01 was considered statistically significant.

Evaluation of Anti-Urolithiasis Activity

Twenty Wistar rats were divided into five groups of four animals each, undergoing different treatments for 28 days. Group I served as the normal control with no treatment. Groups II, III, and IV had *ad libitum* access to regular food and water containing 0.75% ethylene glycol to induce hyperoxaluria and calcium oxalate (CaOx) deposition in the kidneys. Group II received 750mg/kg. Cystone tablets as a standard drug. Groups III and IV were treated with 200mg/kg and 400mg/kg ethanolic extract of *Canna indica* Linn. Rhizome, respectively. Group V served as the positive control, receiving 6μL distilled water per body weight by gavage. After the experiment, 24-hour urine samples were collected and centrifuged to remove faecal contamination. The purified urine was used for further analysis. On the 28th day, rats were anaesthetized, and blood was collected from the retro-orbital sinus. The serum was separated by centrifugation at 10,000 X g for 10 minutes and analyzed for creatinine, urea nitrogen, and uric acid



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using diagnostic kits for calcium, phosphorus, urea, and creatinine 17, 18. The rats were then sacrificed by cervical dislocation, their abdomens opened, and both kidneys isolated and cleaned of extraneous tissue. The right kidney was preserved in 10% neutral formalin, while the left kidney was dried in an oven at 100°C for 24 hours, weighed, and minced in 7ml of 0.5N nitric acid. The calcium content of the mixture was determined using a calcium kit and expressed as mg/g dry kidney. The right kidney was fixed in Bovin's solution, embedded in paraffin, sectioned at 3-4 mm intervals, and stained with hematoxylin and eosin. Tissue slices were photographed using optical microscopy under polarized light.

Statistical Analysis

The results were expressed as mean \pm SEM. Statistical analysis was carried out using one-way ANOVA followed by the Dunnett's test. $P < 0.05$ was considered statistically significant.

RESULT

The powdered Rhizome of *Canna indica* Linn. were extracted by ethanolic extraction technique using a soxhlet apparatus. The percentage yield of ethanolic extract of *Canna indica* Linn. Rhizome was found to be 17.21%W/W. The phytochemical screening of *Canna indica* Linn. Rhizome extracts possess the presence of various chemical constituents such as carbohydrates, flavonoids, saponins, tannins, proteins and amino acids. An increase in urine output is a key index for assessing diuretic effects by estimating the urinary excretion of ions such as Na^+ , K^+ , and Cl^- , identifying the ions responsible for diuretic activity. The extracts significantly increased urinary output compared to the control. *Canna indica* Linn. 200mg/kg (8.17 ± 0.15 ml) and *Canna indica* Linn. 400mg/kg (10.13 ± 0.40 ml) versus control (3.33 ± 0.23 ml; $P < 0.01$). However, this effect was less than that of furosemide (14.26 ± 0.78 ml versus 3.33 ± 0.23 ml). The results indicate that the ethanolic extract of *Canna indica* Linn. possesses dose-dependent diuretic activity at $P < 0.01$. The ethanolic extract increases chloride & sodium ion excretion to a greater extent than potassium, which is an essential quality of a good diuretic with lesser hyperkalemic side effects.

DISCUSSION

Urolithiasis, mainly caused by calcium oxalate (CaOx) stones, involves crystal nucleation, growth, aggregation, and retention in the kidneys. Current treatments manage symptoms but do not directly inhibit CaOx crystallization, a key process in stone formation. Increased oxalate levels lead to oxidative stress, promoting CaOx crystal formation and kidney injury. *Canna indica* Linn. the extract was tested for its anti-urolithiasis effects, showing significant inhibition of CaOx nucleation and aggregation, which helps reduce crystal growth and promote the excretion of smaller particles. Increased oxalate levels predispose the kidneys to oxidative stress by elevating reactive oxygen species (ROS) and reducing endogenous antioxidant enzymes, which facilitates calcium oxalate (CaOx) crystal nucleation, aggregation, and retention. Current treatments primarily focus on reducing urinary supersaturation but do not directly inhibit CaOx crystallization. Inhibiting this process could represent a new therapeutic approach. Nucleation is the initial step in CaOx crystal formation, followed by aggregation, leading to urinary tract occlusion. In this study, *Canna indica* Linn. extracts were tested for their ability to inhibit CaOx crystallization. The results showed that increasing concentrations of *Canna indica* Linn. extract reduced CaOx nucleation and crystal growth, as indicated by lower absorbance values. While the standard solution of Cystone exhibited stronger inhibition, *Canna indica* Linn. still demonstrated significant anti-nucleation properties 19. Aggregation of CaOx crystals is another critical factor in stone formation. *In-vitro studies* showed that *Canna indica* Linn. extract reduced crystal aggregation in a dose-dependent manner. This effect is beneficial as smaller particles are less likely to be retained in the urinary tract and are more easily excreted. Additionally, *Canna indica* Linn. rhizome has a diuretic effect, which may further help in preventing stone formation by increasing fluid output. The extract's ability to inhibit both nucleation and aggregation of CaOx crystals suggests it may be effective in preventing kidney stones by reducing crystal growth and promoting the excretion of small particles 20.



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In-Vivo studies using an ethylene glycol-induced hyperoxaluria model in albino rats demonstrated that *Canna indica* Linn. extract reduced oxalate, calcium, and phosphate excretion, lowering the risk of stone formation. The extract also exhibited diuretic activity, increasing urine volume and the excretion of Na⁺ and K⁺, which likely contributed to the dissolution of pre-formed stones and prevention of new stone formation. The protective effects of *Canna indica* Linn. are attributed to its active phytoconstituents, making it a promising candidate for preventing kidney stones 21, 22. Chronic administration of 0.75% ethylene glycol increased oxalate, calcium, and phosphate excretion, promoting stone formation. Treatment with *Canna indica* Linn. extract and Cystone significantly reduced these elevated levels, preventing stone formation by inhibiting CaOx crystal nucleation and aggregation. The extract also lowered urinary phosphate levels, reducing the risk of calcium phosphate crystal formation 23, 24. The study found that the glomerular filtration rate (GFR) decreased in urolithiasis rats due to urinary obstruction by stones, leading to elevated levels of urea, creatinine, and uric acid in the blood. However, *Canna indica* Linn. extract showed significant diuretic activity, increasing urine volume and the excretion of Na⁺ and K⁺ without altering the Na⁺/K⁺ ratio. This diuretic effect likely contributed to the dissolution of pre-formed stones and prevention of new stone formation 25, 26. The results suggest that *Canna indica* Linn. extract has protective effects against renal calculi by reducing crystal growth and promoting the excretion of small particles, thus preventing kidney stone formation. The presence of active phytoconstituents such as alkaloids, steroids, tannins, phenolic compounds, terpenoids, and flavonoids in the extract may contribute to its efficacy.

CONCLUSION

This study evaluated the diuretic and anti-urolithiasis activities of *Canna indica* Linn. Rhizome extract in Wistar albino rats. The ethanolic extract, containing flavonoids, tannins, terpenoids, and phenolic compounds, showed significant diuretic activity similar to furosemide. This extract also inhibited calcium oxalate (CaOx) crystallization *in-vitro*, suggesting potential benefits for preventing kidney stones. In an ethylene glycol-induced urolithiasis model, ethanolic extract reduced body weight loss, improved urinary output, and decreased the urinary and serum levels of CaOx, phosphate, and uric acid. These effects were comparable to the standard drug, Cystone, indicating ethanolic extract of *Canna indica* Linn. Rhizome potential for treating urolithiasis.

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**In-Vivo Pharmacological Studies****Table No.1. Electrolyte excretion and Diuretic activity of *Canna indica* extract.**

Groups	Treatment & Dose	Cumulative volume of urine (ml/kg BW)	Diuretic action	Electrolyte Concentration			
				Na+	K+	Cl-	Na+/K+
Group I	Normal Control 10ml/kg	3.33 ± 0.23	1.0	85.45 ± 1.13	55.23 ± 0.83	111.50 ± 1.64	155 ± 0.04
Group II	Normal Control 10ml/kg	14.26 ± 0.78	4.3	132.68 ± 0.40	89.83 ± 1.17	134.50 ± 1.64	1.48 ± 0.02
Group III	Ethanolic extract of <i>Canna indica</i> 200mg/kg	8.17 ± 0.15	1.3	85.12 ± 0.26	53.34 ± 1.21	140.34 ± 1.37	1.59 ± 0.04
Group IV	Ethanolic extract of <i>Canna indica</i> 400mg/kg	10.13 ± 0.40	2.7	136.45 ± 0.35	89.50 ± 1.87	132.50 ± 1.05	1.50 ± 0.04

Values are expressed as mean ± SEM. Values are found out by using Student T test.

Table No.2. Ethylene Glycol Induced Urolithiasis model

S. No.	Groups	Calcium (mg/dL)	Phosphorous (mg/dL)	Creatinine (mg/dL)	Urea (mg/dL)
1	Normal control (vehicle)	3.4±0.26	0.8±0.02	0.8±0.04	7.24±0.46
2	Positive control	7.2±0.16	0.2±0.03	9.1±0.16	12.29±0.16
3	Standard Cystone (25mg/kg)	4.6±0.12*	0.74±0.07*	6.4±0.02*	9.7±0.08*
4	Ethanolic extract of <i>Canna indica</i> (200mg/kg)	6.4±0.09*	0.68±0.06*	7.2±0.16*	10.6±0.20*
5	Ethanolic extract of <i>Canna indica</i> (400mg/kg)	5.8±0.13*	0.78±0.04*	6.9±0.16*	8.4±0.20*

Values are expressed as mean ± SEM; P* < 0.05 was considered statistically significant.



**Table No.3. Effect of Rhizome Extract on Ethylene Glycol induced Lithiasis on Urinary Electrolyte Concentration in Wistar Rats.**

S. No	Groups	Calcium (mg/dL)	Phosphorus (mg/dL)	Creatinine (mg/dL)	Urea (mg/dL)
1	Normal control (Vehicle)	6.45±0.06	8.21±0.04	0.35±0.01	3.15±0.05
2	Positive control	9.52±0.10	8.65±0.10	0.60±0.03	37.65±0.10
3	Standard (Cystone) 25mg/kg	7.07±0.06*	7.31±0.06*	0.32±0.02*	27.68±0.03*
4	Ethanollic extract of <i>Canna indica</i> 200mg/kg	7.84±0.08*	8.42±0.09*	0.46±0.01*	26.28±0.07*
5	Ethanollic extract of <i>Canna indica</i> 400mg/kg	7.26±0.076*	8.32±0.07*	0.42±0.01*	21.52±0.05*

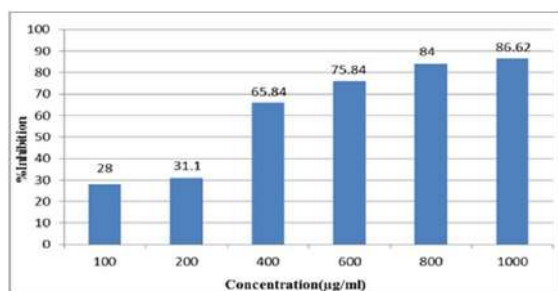
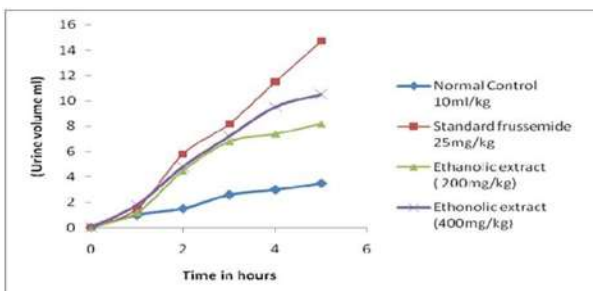
Values are expressed as mean ± SEM; P* < 0.05 was considered statistically significant.

Table No.4. Kidney Calcium Homogenate (µg/gm)

S. No	Groups	Kidney Calcium Homogenate (µg/gm)
1	Normal (Vehicle)	7.65±0.04
2	Positive control	25.62±0.10
3	Standard (Cystone 25mg/kg)	7.58±0.07*
4	Ethanollic extract of <i>Canna indica</i> (200mg/kg)	12.58±0.09*
5	Ethanollic extract of <i>Canna indica</i> (400mg/kg)	6.86±0.07*

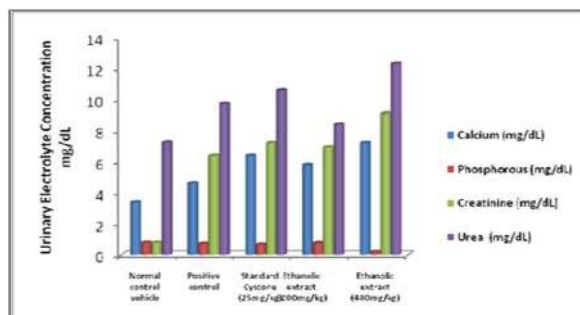
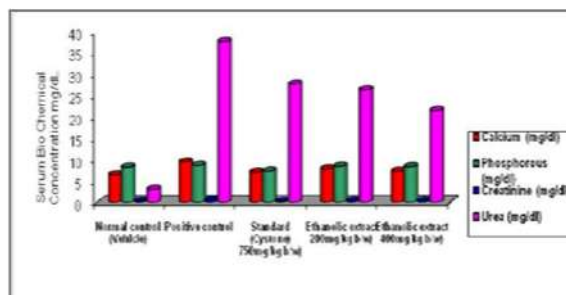
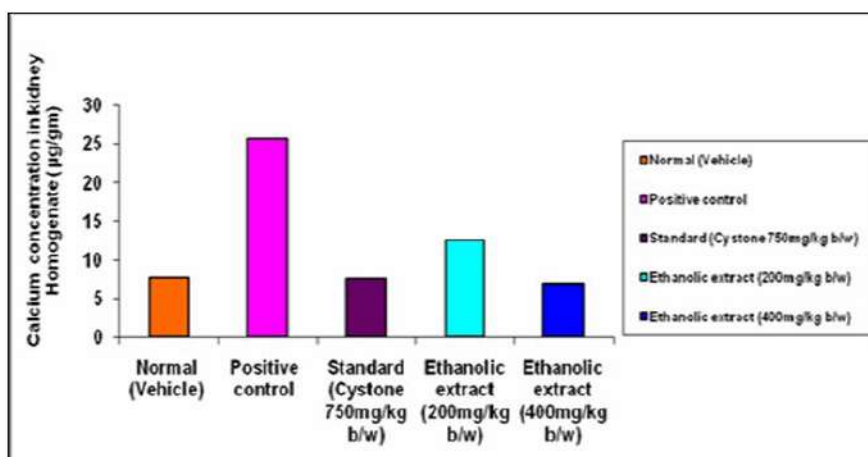
Values are expressed as mean ± SEM; P* < 0.05 was considered statistically significant.

In-Vitro pharmacological Studies

**Figure.1: Effect of ethanolic extract of *Canna indica* on nucleation of calcium oxalate****Figure.2: Time course of diuresis in rats with ethanolic extract of *Canna indica*, and Furosemide**



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Figure.3: Serum Biochemical data on ethanolic extract of *Canna indica* in wistar ratsFigure.4: Serum Biochemical data in ethanolic extract of *Canna indica* in wistar rats.Figure.5. Kidney Calcium Homogenate on ethanolic extract of *Canna indica* in wistar rats



A Study on the Problems and Prospects of Fisheries Sector in Andaman and Nicobar Islands with Special Reference to Port Blair

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ABSTRACT

The fisheries sector stands as a promising subdivision within the broader agricultural domain, with India ranking as the second-largest fish-producing country globally, following China. This sector plays a crucial role in India's economy, contributing significantly to socio-economic development. Recognized as a major source of income and a generator of employment, it also fosters the growth of numerous subsidiary industries. Fisheries are pivotal for providing food, nutrition, income, and livelihoods to millions of people, and they serve as a substantial source of foreign exchange earnings for the country. In the Andaman & Nicobar Islands, a significant proportion of the population, including the fishing community, comprises settlers from mainland India. Originally devoid of traditional fishermen to exploit fisheries resources, the Andaman & Nicobar Administration took proactive measures by relocating traditional fishermen from the mainland to these islands. Despite the implementation of various schemes aimed at enhancing the skills and capabilities of fishermen to foster the growth of the fisheries sector, several challenges persist. The challenges include insufficient skilled and technical manpower, a lack of infrastructural facilities, the absence of boat-building yards, limited local markets, dominance by middlemen, the unavailability of direct export facilities, and a lack of modernized craft and gear. Therefore, this study aims to identify the impediments faced by the fisheries sector and propose suitable recommendations to enhance the prospects of the fisheries sector in the Andaman & Nicobar Islands.

Keywords: Aquatic Animal Production, Boat-Building Yards, Environmental Conservation, Fishing Technology, Nutritious Food.





INTRODUCTION

The fisheries sector stands out as a promising subdivision within India's expansive agricultural domain. Asia, the world's largest continent with a population of 4.2 billion, constitutes 60 percent of the global population. India, as the second most populous country globally with 1.38 billion people, comprises 17.7 percent of the world's population. In India, approximately 65 percent of the population still relies on agriculture for their livelihood, encompassing fisheries as a vital component. The fisheries sector plays a pivotal role in the socio-economic development of the country. Recognized as a potent income and employment generator, it catalyzes the growth of numerous subsidiary industries and serves as a source of affordable and nutritious food, along with being a foreign exchange earner. Consequently, it provides a livelihood for a substantial portion of the economically disadvantaged population in the country. Within the Indian context, the Andaman & Nicobar Islands, a Union Territory, boast an extensive collection of natural resources capable of influencing the islands' economy significantly. The primary sources of revenue in these islands include tourism, agriculture, fisheries, handicrafts, mineral resources, and energy. The fisheries sector, in particular, emerges as a major contributor, providing robust support to the islands' economy. With abundant marine fishery resources, the Andaman & Nicobar Islands consider water resources as a primary means of livelihood, engaging many in fishing activities.

NEED FOR THE STUDY

This study is needed because the fisheries sector plays a vital role in the economy and livelihoods of the Andaman & Nicobar Islands, where many people rely on fishing. Despite efforts to improve the sector, significant challenges persist, limiting its potential. These include a shortage of skilled workers, inadequate infrastructure like boat-building facilities, and limited local markets. Middlemen interference in the supply chain significantly reduces profits for fishermen, while the lack of export facilities restricts access to global markets. Outdated fishing equipment and boats further hinder productivity. These problems affect the income and job opportunities for local communities and slow down overall development. This study aims to identify the key issues facing the fisheries sector and offer practical solutions to address them. By improving infrastructure, providing skill development, and creating direct market access, the study seeks to strengthen the sector, ensuring sustainable growth and boosting economic benefits for both local and national economies.

REVIEW OF LITERATURE

Kumar et.al (2008), in their study "Domestic Fish Marketing" revealed that the infrastructure facilities at the majority of the surveyed landing centers, fishing harbors, as well as wholesale and retail markets are significantly lacking and suffer from poor maintenance. Further it demonstrates the necessity of establishing a consistent market policy for the fishery sector. Such a policy would streamline operations and regulations, thereby ensuring efficient management and the timely delivery of the country's fish production to consumers. Simultaneously, it would also guarantee fair and rewarding prices for fishermen. **Advani et.al (2013)** aimed to examine the "Emergence and Transformation of Marine Fisheries in the Andaman Islands". This study Demonstrate that the large fish exporters have their offices in Port Blair and manage the shipment of processed or frozen fish from the various district of the islands through Port Blair and on Chennai to Mainland India. Direct Export from the Andaman Islands to foreign marketers is not possible due to lack of an international Airport at Port Blair. **Roy and Dorairaj (1994)** examined the socio-economic conditions in the villages of Juglighat and Guptapara, South Andaman, and found that the region's fishing community faces significant development barriers. Key infrastructure, such as ice plants, cold storage facilities, and cooperative societies, were absent near landing centers, hindering fish marketing. Additionally, fishermen had limited access to credit, receiving minimal financial support. The study also highlighted tensions between environmental conservation efforts and the livelihood needs of local fishermen.



**Padhmanaban and Deepa****STATEMENT OF PROBLEM**

The Andaman & Nicobar Islands have significant potential in the fisheries sector promoting large-scale employment and livelihood for coastal communities. The island administration has introduced various schemes to enhance the skills of traditional fishermen, and the sector contributes substantially to the region's economy. However, despite these positives, the fisheries sector faces numerous challenges. These include a critical shortage of skilled and technical manpower, largely due to insufficient training programs for fishermen, limiting their ability to adapt to modern techniques. Infrastructure deficits, such as inadequate cold storage, ice plants, and processing facilities, force fishermen to sell their catch to intermediaries at lower prices, diminishing their profits. Environmental issues, such as rising sea levels, heavy rainfall, and pollution, threaten both the coastal ecosystem and the livelihood of local fishermen. Furthermore, the lack of an international airport in Port Blair restricts export opportunities, while the dominance of middlemen in the local market exacerbates financial pressures. Fishermen also face difficulty accessing financial assistance and credit, especially during lean periods. Additionally, most fishing vessels lack freezing facilities or deep-sea fishing capabilities, and outdated fishing technology hampers productivity. These issues, combined with limited government support and market access, prevent the fisheries sector from realizing its full economic potential.

OBJECTIVES OF THE STUDY

1. To identify the status of fisheries sector in India.
2. To identify the status of fisheries sector in Andaman & Nicobar Islands
3. To study the infrastructural facilities available in study area.
4. To identify the problems faced by the fisheries sector in study area.
5. To offer suitable suggestion for the prospects of fisheries sector in study area.

METHODOLOGY OF THE STUDY

This study has been done on the basis of primary and secondary data. The primary data was collected through interview, schedules and observation from 100 respondents through convenience sampling method. The secondary data are collected through Research papers, articles, journals, books and related websites etc.

LIMITATIONS OF THE STUDY

The study is conducted in Port Blair, the capital city of Andaman and Nicobar Islands. Hence the results may or may not be applicable to the other areas. Moreover the Respondents are often busy during morning hours catching fish, making it difficult to collect data. Additionally, limited access to certain fishing areas and the variability of weather conditions also posed challenges in gathering the data.

STATUS OF FISHERIES SECTOR IN INDIA

The Fisheries is considered as an important sector in India. This sector plays a very important role for the development of the country as it provides employment opportunities to millions of people directly and indirectly and also encourages the growth of a number of subsidiary industries, contributing food security to the country. It plays a vital role in developing the economy through substantial foreign exchange earnings. India is the third largest fish producing and second largest aquaculture nation in the world after China. Around 14 million people are engaged in fisheries and allied activities. The economy of our country has undergone rapid structural changes during the last few decades. In India, Andhra Pradesh is leading in fish production followed by West Bengal and Gujarat. The global fisheries and aquaculture industry reached an unprecedented milestone in 2020, as reported by the Food and Agriculture Organization (FAO) in 2022. The total production soared to a record-breaking 214 million tons, comprising 178 million tons of aquatic animals and 36 million tons of algae. This marked a modest increase of 3 percent compared to the prior record set in 2018 at 213 million tons. However, this growth was tempered by reduced catches of specific fish, declined catches in China, and the adverse effects of the Covid-19 pandemic. The overall trend of aquatic animal production conceals notable disparities among continents, regions, and nations. Asian



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countries led the way in 2020, contributing to 70 percent of the total production, followed by America, Europe, Africa, and Oceania. China retained its position as the top producer, commanding a 35 percent share of total production. The growth of aquaculture over recent decades has significantly contributed to the overall growth of aquatic animal production, elevating it from comprising 12 percent of the total production in the late 1980s to 37 percent in 2020. India, as one of the leading fish-producing nations, plays a significant role in the global fisheries landscape. It ranks as the third-largest contributor to global fish production, accounting for approximately 8 percent of the total. Notably, India holds the second position globally in terms of aquaculture production. The total fish production in India for the year 2021-22 reached an impressive 16.24 million tons, comprising 4.12 million tons from marine fish production and a substantial 12.12 million tons from aquaculture. Projections for the year 2022-23 anticipate a potential exceeding of 174 lakh tons in fish production. India reached an unprecedented pinnacle in its seafood export performance during the fiscal year 2022-23, setting new records in terms of both volume and value. Over this fiscal year, India successfully exported 17.35 lakhs metric tonnes (MT) of seafood, with a total value of Rs. 63,969.14 crores (\$8.09 billion). This marked a significant growth compared to the previous year, with exports surging by 26.73 percent in terms of quantity, 11.08 percent in terms of value, and 4.31 percent in US dollar terms, as reported by the National Fisheries Development Board.

FISHERIES IN ANDAMAN AND NICOBAR ISLANDS

The Fisheries sector is one of the largest industries in the world. It has become a growing industry in recent years. Fishing is one of the earliest known occupations of the people who belongs to an early stage of civilization, acquired for satisfying the food need from natural sources as subsidiary to hunting. Andaman and Nicobar Islands is one of the union territories of India and it consists of around 572 Islands including small and big islands and rocks of which 38 Islands are inhabited. The Andaman & Nicobar Islands have huge potentials for fisheries development in view of its coastal length of about 1962 km and continental shelf area of 35000sq.km. The exclusive economic zone around this island is about 609000sq.km with an estimated fishery potential is 1.48 lakh metric ton which is 3.8% of our country's total fisheries potential. The Andaman & Nicobar Islands have rich marine resources that support a range of fisheries across the length of the island. Initially there were no traditional fishermen in these islands to make use of the fishery resources and hence the Andaman & Nicobar Administration taken initiatives to bring traditional fishermen from different parts of India. Fishermen from Uttar Pradesh, Andhra Pradesh, Kerala and Tamil Nadu come to these islands either through settlement schemes of the government or voluntarily so as to harvest the potential of these islands. Further the Andaman & Nicobar administration brought agriculturists from West Bengal and settled in these islands by providing land for cultivation. These settlers apart from undertaking agriculture were also engaged in fishing in part time and taken up fresh water aquaculture. The Total Fishermen Population is 26,521 as per Marine Fisheries Census 2016 and at present 6088 licensed fishermen are actively engaged in fishing. The marine and inland fish production -43080 metric tons in the year 2020-21. This record has an increase from the previous number of 40801 metric tons for 2019-20. The quantity of marine products exported by firms (Qty in KG)-27,80,385 Amounted to Rs. 18,28,773 for 2019-20.

INFRASTRUCTURE FACILITIES

The Major infrastructural facilities available in Andaman & Nicobar Islands are Fish markets, Fish landing centres, ice processing units, ice plant and cold storage facilities but the availability of these facilities are inadequate. **Figure 1** depicts that the total number of fish markets available in Andaman & Nicobar Islands are 20 out of which 08 fish markets available in south Andaman, 11 available in North & Middle Andaman and 01 market available in Nicobar district. Few places to sell fish mean fishermen can't make much money. This indicates that people can't find many different types of fish to buy. Prices might go up and down a lot because there aren't many sellers. Only a few big sellers might control everything, which isn't fair. It stops the fish business from growing and hurts jobs and how much money we make. It can also make it hard for people to get enough different foods, which isn't good for health. Fixing this needs more places to sell fish, fair competition, better ways to move fish around, and making sure everyone gets a fair share. **Figure 2** depicts that only three fish processing units are available in South Andaman Islands which are completely owned by Private Limited Company. The presence of just three fish processing facilities, all under the ownership of a single private company, presents considerable hurdles for the fisheries



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industry in South Andaman Islands. This monopoly restricts the chances for local fishermen to process and market their catches, diminishing their earnings prospects and suppressing competition. **Figure 3** shows that the total of 15 ice-plant are available in different location of Andaman & Nicobar Islands out of which 04 numbers are owned by the department of fisheries having the capacity of 40 tonnes per day where as 09 numbers of ice plant are owned by different private Limited Companies having the total capacity of 156 tonnes per day and 02 numbers of ice-plant are owned by ANIDCO (undertaking) having the capacity of 10 tonnes per day. The scarcity of ice plant facilities, mostly owned by private entities, presents major hurdles for fishermen. With limited access to these plants, fishermen find it difficult to preserve their catch effectively, resulting in lower quality and value of their products. Private ownership may lead to fishermen encountering high expenses or a lack of ice, affecting their profits. Relying on private ice plants can also expose fishermen to price changes and unfair practices. The inadequate ice plant infrastructure further impedes the growth of the fishing industry. **Figure 4** shows the number of cold storage facilities available in Andaman & Nicobar Islands. Only 12 numbers of cold storage are available out of which 05 are owned by department of fisheries, 06 owned by private companies and 01 owned by ANIDCO (undertaking). The shortage of storage facilities in Andaman & Nicobar Islands poses difficulties for fishermen. Fishermen encounter challenges in adequately preserving their catch. This scarcity can cause spoilage, lower product quality, and restrict market access. Moreover, relying on a small number of storage facilities may lead to higher expenses or insufficient capacity during peak fishing times.

Problems confronted by fisheries Sector in Andaman & Nicobar Islands

Andaman & Nicobar Islands being recognised as one of the major thrust area through marine fisheries. The main source of generating revenue in these islands are tourism industry, fisheries sector, handicraft industries, energy and sources, among fisheries is one of the major sources of generating revenue. The total number of fishing crafts in the island is 2946 and the total number of landing centre is 33. It also promotes large scale employment and livelihood of coastal communities. The island administration introduced number of schemes for enhancing the skills and capabilities of the traditional fishermen hence it plays significant role in trade and commerce. Fisheries governance in Andaman and Nicobar islands is promptly implementing various schemes and programmes for the development of fisheries sector. Despite of having these benefits, the fisheries sector in this islands confronted by numerous hurdles.

- i. It is observed from the study that there is a lack of skilled and technical manpower in the study area. Hence the non availability of manpower is one of the major drawbacks which affect the growth of the fisheries sector. This is due to lack of necessary training imparting to the fishermen.
- ii. The infrastructural facilities such as cold storage, ice plant, transportation, processing plant, landing centre and availability of boat yielding yards plays a vital role for the growth and development of fisheries sector but it is found from the study that the fishermen lacks such infrastructural facilities in the study area and they do not have sufficient cold storage to keep their catch and store the unsold fish. Most of the fishermen do not rely on private traders for storing their fishes due to higher cost since they are not able to bear such expenses. Due to this they forced to sell their catch to the intermediaries,
- iii. It is found from the study that the fishermen export the fishes from Andaman & Nicobar Islands up to Chennai and some other states within India. Export to foreign countries not taking place in the study area due to the non availability of international airport at Port Blair.
- iv. Middle men dominance is also one of the major problem confronted by fishermen due to the lack of awareness about the market condition, insufficient storage facilities, poor transportation and lack of information about the potential customers, the small fishermen are not able to sell their catches directly to the consumer. Hence they mostly depend on the middlemen to sell their fishes at a low cost and the same has been sell by the middlemen to the consumer at a higher price due to this the fishermen fails to enjoy the entire profit.
- v. It is found from the study that environmental constraints such as heavy rainfall, raising sea level, flood, pollution or ocean acidification also one of the major hurdles of the fisheries sector which not only affect the productivity of the coastal fisheries but also the livelihood of the fishermen.
- vi. It is observed from the study that the fishermen get a little or no financial assistance and credit from various agencies and government during the lean period.



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- vii. It is observed from the study that most fishing vessels do not have the freezing facility to freeze the fish immediately after catching which leads to inferior quality and most of the vessels do not have the sufficient equipment to go for deep sea fishing.
- viii. Lack of technology also one of the obstacles that affect the growth of fisheries sector. The fisher folk community still uses the outdated technology for catching, they are not able to use the new techniques due to less income and limited support from government.

SUGGESTIONS

The following are the suggestions for the growth of fisheries sector in Andaman and Nicobar Islands

- i. The government must initiate awareness programs for fishermen, educating them on the latest technologies through essential training sessions. By equipping them with knowledge about modern tools and techniques, fishermen can enhance efficiency, productivity, and sustainability in their operations, ensuring the advancement of the fishing industry.
- ii. The Department of fisheries should establish more ice-plant and cold storage facilities at different places in the islands for fisheries sector and provide the same at a very reasonable rate to the fishermen.
- iii. Transportation facilities such as a separate tempo or mini van should be explored for transporting the fresh and dried fish at least for the members of cooperatives at a minimum cost. The government should allocate funds or provide subsidies to support the procurement of tempos or mini-vans and cover operational expenses. It's vital to collaborate with local cooperatives and stakeholders to customize transportation solutions that cater to fishermen's distinct requirements. Moreover, establishing regulatory frameworks is essential to ensure the smooth operation of these services, promoting fair pricing and accessibility for cooperative members.
- iv. Alternative job opportunities should be provided to the fishermen during the lean periods and welfare funds should be given during the natural calamities so as to compensate the loss sustained by the fishermen. During lean fishing seasons, fishermen could participate in aquaculture, tourism-related endeavors like boat tours or guiding, marine conservation projects, fish processing, community development efforts, or education and training programs. These avenues offer extra income and skill enhancement, bolstering financial stability during periods of low fishing activity.
- v. The fisheries cooperatives need to be strengthened and enough support should be provided to the fishermen to sell their catch directly to the consumer without the role of middlemen interference. The government's focus should be on bolstering fisheries cooperatives through financial aid, technical assistance, and capacity-building initiatives. Furthermore, it should establish regulations to enable fishermen to directly sell their catch to consumers, reducing middlemen interference. This might include developing market infrastructure, enforcing fair trade policies, and incentivizing cooperative growth. By empowering fishermen and facilitating direct market access, the government can improve their livelihoods and promote sustainable development in the fishing industry.
- vi. Provide adequate incentives and steps to be taken to encourage the growth of export. To promote fish export growth in the Andaman Islands, the government must invest in port infrastructure, improve quality control measures, engage in trade negotiations, market Andamanese fish products, provide financial aid, support research, offer skill development, and streamline regulations. These actions will enhance competitiveness and market accessibility, fostering fisheries sector export expansion.
- vii. Periodic awareness programs should inform fishermen about available incentives and subsidies. These programs should highlight various government schemes supporting the fisheries sector, explaining eligibility criteria, application procedures, and benefits. Accessible materials, workshops, and community outreach efforts ensure fishermen are informed and can take advantage of available support effectively. The Government should utilize diverse communication channels like radio, community gatherings, mobile apps, and printed materials to inform fishermen about government schemes. Partner with local authorities, fisheries cooperatives, and NGOs to conduct workshops and training, ensuring fishermen grasp eligibility criteria, application procedures, and benefits of the schemes effectively.





CONCLUSION

The fisheries sector in Andaman & Nicobar Islands is not only a source of generating revenue for the islands but also a source of livelihood for the coastal communities. Large section of people directly or indirectly relying on fisheries sector. The island administration introduced various schemes to enlarge the skills and capability of fisher folk for the expansion of fisheries sector even though the fisheries sector facing numerous challenges. Hence the government should take initiative to uplift the status of fisheries sector by providing necessary infrastructural facilities, latest equipment and financial support to the fishermen for marketing the fishes which would in turn not only reduce the stress of the fisher folk but also helps in progress the fisheries sector.

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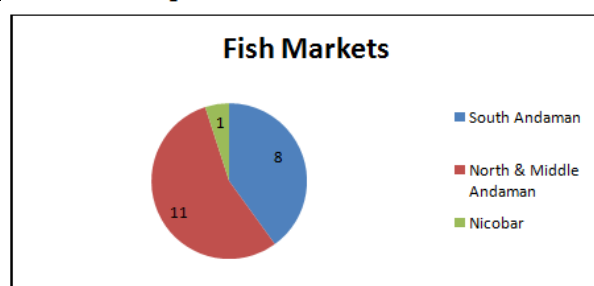


Figure 1: Number of Fish Markets
Source- Directorate of Fisheries, Andaman & Nicobar Administration

Sl.No	Name of processing Unit	Capacity (Tonnes/day)	Year of Construction
1	M/s Era Fishery Product Private Ltd., Dollygunj	05	2012
2	M/s Rubin Sea Food, Shiprighat	06	2010
3	Monsoon Fisheries Dhanukari	08	2015
Total		19	

Figure 2: Fish processing Units
Source- Directorate of Fisheries, Andaman & Nicobar Administration

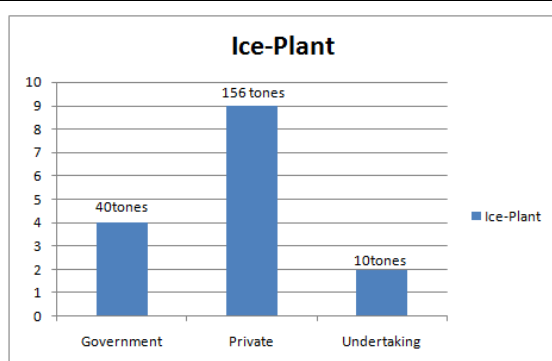


Figure 3: Ice Plant
Source- Directorate of Fisheries, Andaman & Nicobar Administration

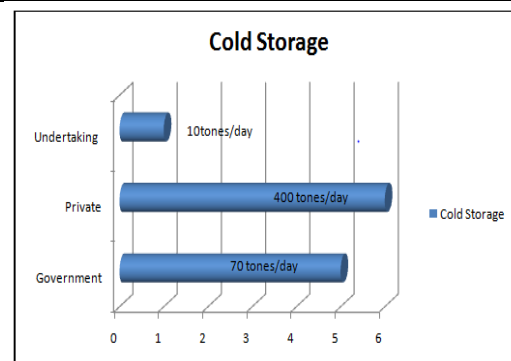


Figure 4: Cold Storage
Source- Directorate of Fisheries, Andaman & Nicobar Administration





Identifying a Person by Audio Aesthetic using Machine Learning

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ABSTRACT

This research paper presents a novel approach for identifying a person by audio aesthetics, focusing on a dataset of 50 speakers, each represented by multiple audio clips of their voices. Leveraging the unique emotional and cognitive responses individuals exhibit towards their vocal characteristics, this study aims to establish a reliable biometric identification system based on audio aesthetic preferences. The proposed framework utilizes a Convolutional Neural Network (CNN) to automatically extract high-level features from the audio clips, enabling the system to capture the distinctive qualities of each speaker's voice. The methodology involves a three-stage process: first, audio clips are transformed into mel- spectrograms to facilitate effective feature extraction; second, a CNN architecture is employed to extract discriminate features from these mel-spectrograms; and third, a classifier is trained to identify individuals based on their audio aesthetic profiles. Experimental results demonstrate that the proposed system achieves an impressive identification accuracy of 96% across the dataset, significantly outperforming traditional methods reliant on handcrafted features.

Keywords: Convolutional Neural Network, Mel-Spectrogram, Ensemble learning





INTRODUCTION

In the field of biometric identification, the exploration of audio aesthetics as a means of recognizing individuals has gained significant interest. This study focuses on the unique vocal characteristics of 50 speakers, each represented by multiple audio clips of their voices. By leveraging the emotional and cognitive responses individuals exhibit towards their vocal expressions, this research aims to establish a reliable system for identifying a person using audio aesthetic. The proposed framework uses a Convolutional Neural Network (CNN) to automatically extract high-level features from the audio clips, capturing the distinctive qualities of each speaker's voice. This approach not only enhances the accuracy of identification but also reduces the need for extensive feature engineering typically associated with traditional methods.

Literature Survey

This research focuses on "Aesthetic Net," a deep convolutional neural network created by A. H. Bari, B. Sieu, and M. L. Gavrilova for person recognition using visual aesthetic qualities. The study, published in *The Visual Computer*, investigates the use of aesthetic features as a distinguishing factor in identity detection, which broadens existing biometric approaches. The authors suggest a methodology that uses aesthetic features like color, style, and composition to improve the accuracy of person recognition. Aesthetic Net has considerable potential for applications where conventional biometric data is restricted, providing a fresh approach to identification using visual aesthetics.

METHODOLOGY

- **Speakers:** A total of 50 unique speakers, each contributing to the dataset.
- **Audio Clips:** Each speaker is represented by multiple audio clips of their voices, specifically selected to capture their vocal characteristics and aesthetic preferences.
- **Audio Length:** Each audio clip is approximately 30 seconds long, ensuring sufficient data for feature extraction.
- **Diversity:** The audio clips encompass a variety of genres and styles to reflect the speakers' diverse musical tastes and preferences.
- **Data Format:** The audio files are stored in a standard format (e.g., WAV or MP3) to facilitate processing and analysis.
- **Labeling:** Each audio clip is labeled with the corresponding speaker's identity, allowing for supervised learning during the training of the machine learning model.

Data set

The dataset comprises audio recordings from 50 distinct speakers, each contributing a varying number of samples. To prepare this raw data for deep learning model development, extensive preprocessing was necessary to extract meaningful representations. The model's performance was assessed using a dedicated test set, which was set aside during the training and validation phases. This test set includes audio samples and corresponding speaker labels that the model did not encounter during development, making it representative of the real-world scenarios the model will face upon deployment. Approximately 10-20% of the total dataset was designated for the test set, ensuring that the evaluation reflects the model's ability to generalize to new, unseen data effectively. This careful division allows for a robust assessment of the model's identification capabilities.

Proposed System

The model utilizes mel-spectrogram audio features, capturing both temporal and spectral information from voice samples. It begins with 1D convolutional neural networks (CNNs) employing ReLU activation to extract low-level speech features by identifying local patterns in the spectrogram. This is followed by recurrent layers, such as LSTM and GRU, which model temporal context and long-range dependencies to capture distinctive voice characteristics. The extracted features are then classified into enrolled speaker IDs using fully connected dense layers and a soft max



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output layer. Categorical cross-entropy loss trains the model, with dropout regularization preventing over fitting. The dataset is divided into training, validation, and test sets, with performance metrics like accuracy and F1-score assessed on the test set for evaluation.

Process Involved**Dataset**

Data collection for identifying a person by audio aesthetics, involves gathering audio samples from 50 speakers. In this study, publicly available audio datasets were used, consisting of 400 instances with 25 acoustic features each. The target variable represents speaker identity, and the dataset is imbalanced, with 150 samples from some speakers and 250 from others. Features like Mel-frequency cepstral coefficients (MFCCs) and Chromagram are used to capture unique audio traits. The dataset includes independent attributes representing voice characteristics, and using a larger set of features improves the accuracy of speaker identification through machine learning models.

DATA CLEANING

Data cleaning for identifying a person by audio aesthetics, involves several steps. First, corrupted audio files and those with excessive background noise are removed or repaired. Volume levels are normalized, and silence is trimmed from the beginning and end of recordings. All audio files are converted to a consistent format, such as mono-channel .wav at 16kHz. Speaker labels are verified to ensure accuracy. Noise reduction techniques are applied, and outliers or distorted samples are removed. Finally, consistent sample lengths are maintained through trimming or padding, ensuring the dataset is clean and ready for machine learning models.

Data Scaling

Data scaling involves converting audio properties to suit a given range, such 0-1. For models that are sensitive to the size of input characteristics, such as support vector machines (SVM) and k-nearest neighbors (KNN), this phase is particularly important. To normalize the audio data in this investigation, which focused on person identification using audio aesthetics from 50 speakers, we used the maximum absolute scaler approach. By using this method, the machine learning algorithms performed better, guaranteeing a more accurate and efficient speaker recognition procedure.

Data Analysis

In data analysis, pertinent audio characteristics including spectral contrast and Mel-frequency cepstral coefficients (MFCCs) are extracted and assessed. Each speaker's speech is examined for trends and differences using these characteristics. The audio data that has been processed is subsequently used to train machine learning algorithms, such as neural networks and support vector machines (SVM). The efficacy of these models in differentiating between speakers is evaluated by criteria such as accuracy, precision, and recall. Strong identification systems based on audio aesthetics can be developed thanks to this approach.

Data Balancing

Data balancing is essential for ensuring that machine learning models accurately represent all classes within a dataset, particularly in the context of person identification using audio aesthetics. In this study, we addressed the class imbalance present in our audio dataset, which includes recordings from 50 speakers. Since certain speakers may have significantly more audio samples than others, this imbalance can lead to biased models that favor the more represented classes. To achieve data balancing, we employed techniques such as oversampling the minority class (adding duplicate samples or generating new synthetic samples using methods like SMOTE) and under sampling the majority class (reducing the number of samples from over represented speakers). This process helps create a more equitable distribution of audio samples across all speakers, allowing the machine learning models to learn equally from each class. As a result, the identification system can improve its accuracy and robustness, leading to better performance in real-world applications.



**Matrix Correlation**

Matrix correlation plays a vital role in person identification using audio aesthetics by assessing the relationships between various acoustic features extracted from audio samples. By calculating a correlation matrix, we can understand how features like Mel-frequency cepstral coefficients (MFCCs), chromagrams, and spectral contrast interact. High correlation values may indicate redundancy, suggesting some features can be discarded without compromising performance. In contrast, low or negative correlations reveal unique characteristics that aid in speaker differentiation. This analysis informs feature selection, enabling a more efficient and effective feature set for training machine learning models, ultimately enhancing the identification process of individual speakers.

Classification Algorithms**a.CNN**

Convolutional Neural Networks (CNNs) analyze distinctive elements taken from audio sources to identify individuals. To process the audio data, the CNN architecture uses a number of convolutional layers, pooling layers, and activation functions. In order to generate a unique signature for every person, the network learns to recognize distinguishing patterns in the audio signals, such as spectral properties, rhythm, and tone. The CNN learns and adjusts its parameters for precise identification by being given audio samples from different people during training. The CNN achieves high accuracy rates in speaker recognition tasks after being trained to identify unknown audio samples as belonging to a certain individual. CNNs can successfully capture the subtleties of a situation by utilizing the advantages of deep learning.

b.RNN

By simulating temporal correlations in audio inputs, Recurrent Neural Networks (RNNs) perform exceptionally well in person identification tasks. Sequential audio data is processed by RNN architectures, like Long Short-Term Memory (LSTM) or Gated Recurrent Units (GRU), which identify patterns and connections among auditory parameters. Speech patterns, tone, and spectral properties are among the speaker-specific attributes that the network learns to encode into a condensed form. RNNs optimize their weights during training in order to reduce speaker identity prediction errors. Accurate identification is made possible at inference, where the trained RNN receives an audio sample and produces a probability distribution across potential speaker identities. In noisy or deteriorated audio settings, RNNs outperform conventional techniques for speaker recognition due to their capacity to handle variable-length input sequences and simulate long-term dependencies.

c. LSTM

A specific kind of Recurrent Neural Network (RNN) called Long Short-Term Memory (LSTM) networks is excellent at identifying long-term patterns and temporal connections in sequential data, like audio signals. Strong speaker recognition and verification are made possible by LSTMs' efficient modeling of complicated dynamics and interactions in speech through the use of memory cells, input gates, output gates, and forget gates. Even in noisy or deteriorated audio environments, LSTMs are able to achieve high accuracy in person identification by extracting unique speaker-specific properties such as tone, rhythm, and spectral characteristics. Because of this, LSTMs are a dependable option for a number of uses, such as emotion detection, language modeling, and speech recognition.

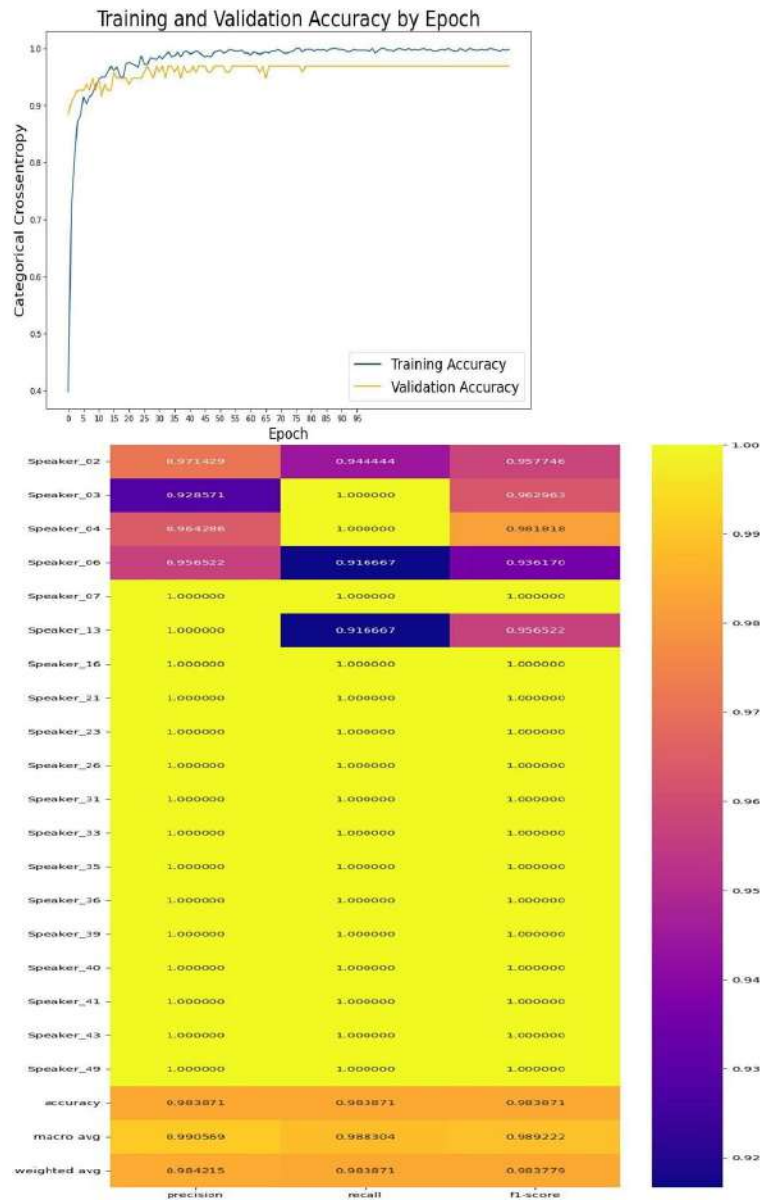
d.GRU

One kind of recurrent neural network (RNN) called a gated recurrent unit (GRU) is made to effectively capture temporal dependencies in sequential data, such audio signals. By combining the input and forget gates, GRUs streamline the conventional LSTM architecture, lowering computational complexity without sacrificing performance. GRUs can learn long-term patterns and relationships thanks to their simplified design, which makes them ideal for time series forecasting, language modeling, and speaker recognition. Even in loud or deteriorated audio environments, GRUs are able to identify speakers with high accuracy by extracting speaker-specific properties from audio signals, such as speech patterns and spectral characteristics.





RESULT



CONCLUSION

In conclusion, applying a Convolutional Neural Network (CNN) for person identification using a dataset of 50 different speakers proved to be highly effective. By transforming audio clips into mel-spectrograms and automatically extracting high-level features using a CNN, the system was able to capture the distinctive vocal characteristics of each speaker. The approach demonstrated a significant improvement in identification accuracy, reaching an impressive 96%. This shows the potential of deep learning-based models like CNNs in eliminating the

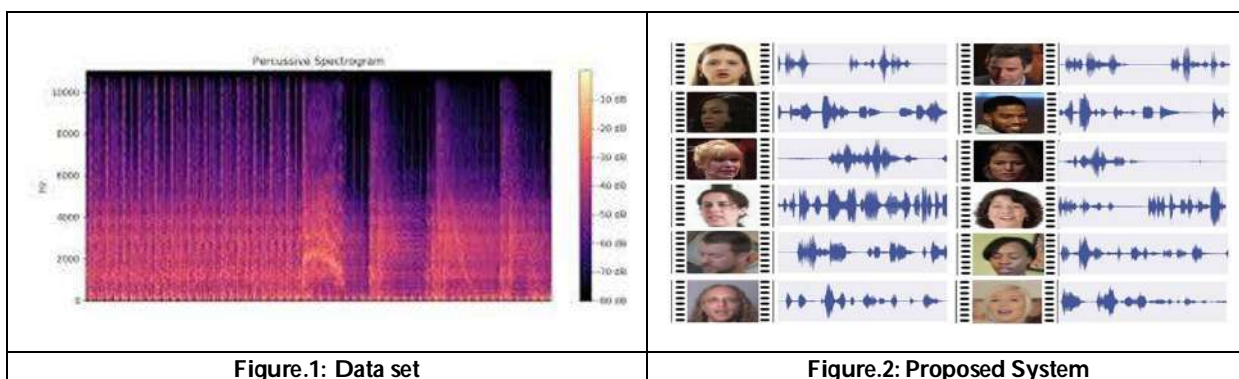




need for manual feature engineering, as they can automatically learn discriminative audio features, even in complex datasets involving multiple speakers.

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Neurological Evidence and impact Bias in Legal Proceedings: the Impact on Society

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ABSTRACT

The use of neurological evidence in legal contexts has created new opportunities for addressing implicit biases during courtroom proceedings. Unconscious attitudes known as implicit biases can present major obstacles in guaranteeing fair trials and equitable treatment in the justice system by impacting perceptions and decision-making. New investigations in neuroscience are starting to clarify the brain processes behind these predispositions, providing understanding on how they appear and impact decision-making and actions. This article investigates how neurological evidence, such as brain imaging and cognitive assessments, can be used to discover and measure implicit biases in legal professionals, jurors, and witnesses. Through analyzing specific cases and new developments in neuro technology, the research underscores the possible advantages and moral quandaries of integrating neurological proof into legal systems. Topics like the trustworthiness, availability, and difficulties in understanding this evidence are examined, as well as the impact on policy changes. This evaluation highlights the importance of neuroscientists, sociologists, and legal experts working together to develop a fair approach that upholds individual rights and ensures judicial fairness. The paper suggests further research to investigate how neurological evidence can help reduce bias and improve the reliability of legal proceedings.

Keywords: Evidence, Neurology, Judicial Fairness, Brain Imaging, Trial System.

INTRODUCTION

Unconscious attitudes and stereotypes that influence behavior, known as implicit bias, have become a significant issue in ensuring fair and unbiased judicial proceedings. Research [1] suggests that implicit bias can result in notable differences in legal outcomes, affecting jury verdicts, sentencing decisions, and evaluations of witness credibility.



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Recently, progress in neuroscience has led to a better understanding of how implicit biases develop and operate in the brain, especially through neuroimaging methods that uncover neural processes. Research indicates that certain parts of the brain, like the amygdala, are essential for instinctual reactions linked to bias, whereas the prefrontal cortex helps to control and suppress these prejudices [2]. The inclusion of neurological evidence in legal contexts is still debated, prompting inquiries about its trustworthiness, acceptability, and moral consequences. The legal system typically uses behavioral and circumstantial evidence to evaluate bias, but incorporating neurological evidence may offer a more impartial way to measure implicit bias [3]. This article examines how neurological evidence can be used to address implicit bias in courtrooms, taking into account the validity of the science and the ethical issues involved. This study aims to investigate if evidence from neuroscience can enhance judicial fairness and help create policies that reduce bias in legal proceedings by exploring the connection among neuroscience, implicit bias, and law.

Objectives of The Study

The objectives of this paper are as follows:

- To study the neural mechanisms of implicit bias, investigate the scientific foundation of implicit bias by looking at the brain areas and neural systems that play a role in creating and controlling these biases.
- To review the criteria for presenting neurological evidence in courts, addressing issues concerning trustworthiness, understanding, and the legal guidelines controlling this type of evidence.
- To examine the ethical issues and legal factors associated with utilizing neuro-evidence for evaluating implicit bias, emphasizing individual rights, mental privacy, and due process.
- To provide suggestions for policies that can be used to integrate neuroscience into the legal system in a responsible manner to reduce implicit bias, improve fairness, and promote reform within the judiciary.

MATERIALS AND METHODS

This article employs a blended methodology, merging an extensive literature review with qualitative case analysis to examine how neurological evidence is utilized to tackle implicit bias in courtrooms. Essential materials consist of peer-reviewed articles on neuroscience, implicit bias, and legal studies for grasping the neural foundation of bias, its effect on legal results, and present courtroom procedures. Studies published from 2000 onwards were gathered from databases like PubMed, JSTOR, and LexisNexis, with a focus on articles utilizing neuro imaging techniques (fMRI, EEG) in bias research.

The Neuroscientific Foundation Of Implicit Bias

Implicit biases are ingrained prejudices and stereotypes that impact how individuals perceive, assess, and behave without conscious recognition. Research in neuroscience has improved our comprehension of how biases are created and maintained by the brain, mainly involving structures such as the amygdala and the prefrontal cortex. The amygdala, responsible for managing emotional responses, has a key role in the immediate, involuntary reactions seen in implicit bias. The reactions often stem from connections to cultural stereotypes or past experiences stored in memory [4]. Research indicates that amygdala activation can happen even when a person is unaware of their biases, indicating that subconscious neural processes underlie implicit attitudes [5]. The prefrontal cortex, which handles advanced cognitive processes such as self-control, plays a role in overseeing and at times suppressing these ingrained biases. Studies show that when people try to suppress implicit biases, the prefrontal cortex, specifically the dorsolateral prefrontal cortex, is highly involved, as it helps regulate emotional reactions [6]. Nevertheless, the prefrontal cortex sometimes fails to suppress these biases due to the amygdala's dominance, especially when facing time constraints or mental strain [7]. The measurement of implicit bias is often done through tools such as the Implicit Association Test (IAT), which identifies biases by monitoring reaction times to related words or images. Research using fMRI has revealed that individuals with elevated levels of implicit bias on the IAT tend to display increased amygdala activation when seeing faces from racial out-groups [8]. This indicates a brain counterpart for subconscious biases that appear involuntarily. Although these tools are helpful, discussions continue about the accuracy of the IAT in measuring implicit bias due to potential impacts of situational factors on response times [9].



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Implicit biases may also have roots in evolutionary processes that prioritize quick categorization for survival. This natural tendency, referred to as "in-group" preference, helped early humans differentiate between allies and enemies, a crucial ability for ensuring survival [10]. Even though it was helpful in ancient human communities, this natural inclination now causes social rifts, as the brain sorts people into groups using physical characteristics like race or gender, often resulting in bias [11]. Research in neuroscience indicates that these classification processes are mostly automatic and subconscious, based on neural pathways that prioritize efficiency rather than accuracy [12]. Adding more complexity to implicit bias is the idea of neuroplasticity, which refers to the brain's capacity to restructure itself through the creation of fresh neural pathways. Research has shown that continual exposure to various social interactions can decrease amygdala reactivity and lessen implicit biases in the long run [13]. These results indicate that implicit biases can change in response to social environments, showing promise for reducing bias with specific interventions [14]. Yet, applying these neuroscience findings to real-world actions continues to be difficult in social and legal settings, because these prejudices frequently function without being consciously recognized. The legal field can be greatly impacted by the neuroscientific understanding of implicit bias, especially in terms of its influence on jury selection, sentencing, and overall judicial equity. Neuroscientific evidence could offer a more objective way to examine unconscious biases in courtrooms by pinpointing the neural foundation of implicit biases. Still, the incorporation of this evidence is a subject of disagreement because biases linked to neural processes pose a challenge to conventional legal ideas of intent and culpability [15]. Moreover, there are ethical issues regarding mental privacy and the potential inappropriate use of neurological evidence in legal contexts, with some stating that discriminatory actions should not be justified by implicit biases [16]. The research in neuroscience shows that unconscious biases are ingrained in brain functions, particularly in the amygdala's reflex reactions and the prefrontal cortex's executive control. Although these biases may have served a purpose in evolution, they frequently result in discriminatory results in today's world. Comprehending the neural foundation of unconscious prejudices provides chances for reducing biases and promoting more equitable legal systems, yet it also brings difficulties in implementing these findings into practical legal structures.

The Admissibility of Neurological Evidence In Bias-Related Legal Cases

The acceptability of neurological evidence in bias-related legal cases has become a complicated and developing issue. Neurological evidence, frequently obtained from neuroimaging methods like fMRI or EEG, can provide valuable understanding of implicit biases through detecting brain patterns associated with automatic attitudes and stereotypes. While the evidence could improve comprehension of implicit bias, its application in courtrooms faces legal and ethical obstacles. The Daubert and Frye standards [17] are crucial for determining the acceptance of neurological evidence in the U.S. legal system, establishing guidelines for evidence's scientific reliability and widespread acceptance. According to the Daubert standard, the evidence needs to show reliability, relevance, and a solid scientific foundation. Courts have to evaluate if the neurological evidence meets these standards by examining the methodology and the capability to accurately interpret results. Still uncertain is whether fMRI and EEG studies have achieved the necessary reliability for reliable legal use, given their susceptibility to context and the need for expert interpretation [18]. A significant legal issue is the excessive interpretation of neuro-evidence. Brain scans do not offer direct proof of particular thoughts or intents, but rather show indirect signs of brain activity linked to mental processes. Critics contend that utilizing brain scans to evaluate implicit biases may result in misinterpretations, as biases identified in a controlled environment may not necessarily align with actions in real-life situations [19]. Furthermore, implicit biases are frequently influenced by the context, which implies that biases identified in an experimental environment may not be present in other scenarios, making their use as conclusive legal proof more challenging [20]. Interpreting neurological data can be challenging due to its subjective nature, leading to inconsistent application in different cases. Courts are at risk of encountering variability in expert testimony due to experts offering differing interpretations of the same neuroimaging data. This variation gives rise to worries about the possibility of bias when interpreting neurological evidence, making it more challenging to use in determining factual evidence for cases involving implicit bias [21]. Ethical issues also come up regarding the protection of privacy and mental well-being. Studying an individual's brain processes through neurological evidence raises worries about mental privacy and self-incrimination [22]. Critics caution that introducing neuro-evidence about implicit biases may violate an individual's mental privacy, possibly categorizing people based on unconscious beliefs rather than



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intentional behaviors. These worries align with the ethical guidelines of the American Bar Association, which prioritize safeguarding individual rights and steering clear of evidence that may result in unjust bias. Although the neurological evidence offers interesting potential for evaluating implicit biases in legal cases, its acceptance in court is challenged by significant scientific, interpretive, and ethical obstacles. Courts need more specific guidelines in order to assess the reliability and relevance of neuro-evidence, making sure it meets legal and ethical standards. Using neurological evidence as a supplement rather than a main focus can offer a balanced strategy, enabling us to acknowledge its benefits without relying too heavily on its constraints.

The Impact of Neurological Evidence And Court Room Bias In Society

The inclusion of neuroscientific findings in legal cases has important consequences for combatting biases in court that impact the impartiality of judicial decisions. In legal situations, implicit biases, which are unconscious attitudes and stereotypes that can affect decisions, are widespread and affect jurors, judges, and lawyers [23]. Neurological evidence, especially from methods like fMRI, is now seen as a possible way to comprehend and reduce biases by identifying the brain activity related to decision-making. Studies show that unconscious biases can result in unequal treatment due to race, gender, or income level, causing systemic disparities in the legal system [24]. Studies indicate that jurors might unknowingly link Black defendants with increased criminality, leading to more severe judgments and sentences [25]. Legal scholars and practitioners are using neurological evidence to understand how biases manifest in courtroom proceedings, aiming for a more impartial perspective [26]. Using neurological evidence to evaluate bias brings about both chances and difficulties. It provides a scientific foundation for comprehending the functioning of biases at a subconscious level, potentially influencing jury selection and judicial training [27]. To illustrate, identifying the areas of the brain linked to partial decision-making could assist legal experts in creating methods to address these biases with educational and awareness programs [28]. Moreover, integrating neurological evidence in legal proceedings could lead jurors and judges to address their biases directly, encouraging a sense of responsibility within the legal system [29]. Nevertheless, incorporating neurological evidence also gives rise to important ethical and practical issues. Deciphering neuroimaging findings can be intricate and may be misinterpreted if not accompanied by sufficient context [30]. In other words, detecting bias through neural signatures does not necessarily prove a person's intent or guilt, which can make legal arguments about responsibility more complex [31]. Additionally, the possibility of neurological evidence strengthening stereotypes or continuing biases raises ethical concerns about mental privacy and individual rights [32]. Another important issue is the risk of depending too much on neurological evidence, resulting in a simplified perspective of human behavior. This viewpoint may oversimplify intricate social dynamics and fail to consider the socio-legal factors influencing bias [33]. Legal professionals must find a middle ground between applying knowledge from neuroscience and having a comprehensive grasp of the complex aspects of human conduct, especially when in a legal setting. In spite of these obstacles, the neurological evidence has the ability to greatly impact how bias and fairness are perceived in the judicial system. By recognizing the scientific foundations of implicit bias, society can encourage a more knowledgeable conversation about justice and equality [34]. Educational programs for legal professionals, based on neuroscience research, are a key strategy to decrease bias in the courtroom and improve the fairness of the judicial system.

CONCLUSION

Examining neurological evidence in legal cases showcases an important overlap among neuroscience, psychology, and law, especially in regards to implicit biases that may impact court decisions. Since implicit biases work without awareness, they present major obstacles to achieving fairness and justice in the legal system. Advanced imaging techniques provide valuable neurological evidence that helps us better understand the biases in decision-making in courtrooms by revealing the neural mechanisms behind them. Although there are significant advantages to incorporating neurological research into legal procedures, such as improving jury selection, educating judges, and increasing awareness of biases, it is important to acknowledge the difficulties as well. Issues concerning the trustworthiness and interpretive intricacies of neuro imaging data need to be resolved to guarantee proper and





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ethical utilization of this evidence. Furthermore, depending too much on neurological evidence can result in simplifying human behavior and overlooking the intricate social factors that contribute to bias in the legal system. In the end, the proper integration of neurological evidence in the legal system could lead to a fairer judicial process. This integration presents ethical and practical challenges that can be addressed through collaboration between legal professionals, neuroscientists, and ethicists. Through focusing on education and awareness efforts guided by neuroscientific discoveries, the legal field can aim to lessen the influence of unconscious biases, ultimately improving the fairness of legal processes. By taking this action, society can make significant progress in tackling systemic inequalities and advocating for justice for everyone.

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Impact of Covid-19 Outbreak on Tourists Inflow in Andaman and Nicobar Islands

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ABSTRACT

Tourism is a major industry in Andaman and Nicobar Islands. The Andaman and Nicobar Islands are the exclusive tourist destination. The natural beauty of the A& N Islands is very attractive. The majority of the revenue earned by the government of Andaman and Nicobar is through the tourism industry. Therefore it is a very important foundation for generating income which is created through spending by tourist inflow. The outbreak of COVID-19, a black swan event had an extreme impact on tourist inflow in A& N Islands in the past four years that is from 2018-2022. The nationwide lockdown in different nations restricted various economic activities and movements. Tourism is one of the economic activities severely hit by COVID-19 in the A & N Islands. According to the study, the tourist inflow rate was 17.44 % in A & N Islands in 2017-18. In the next year 2018-19, the rate of tourist inflow was 0.19% and the rate went negative in the next year 2019-2020 which is -84.39%. Due to the COVID-19 outbreak, tourist arrival declined which has serious consequences on the livelihood of the islanders. This study reveals the impact of the COVID-19 outbreak on both domestic and foreign tourist inflow in the Andaman & Nicobar Islands. This paper is entirely based on secondary data collected from websites, articles, and Tourism Statistics issued by the Directorate of Tourism, Andaman and Nicobar Administration.

Keywords: COVID-19, Environment, Lockdowns, Pre-Pandemic, Tropical Climate, Tourists Inflow.





INTRODUCTION

A paragon of beauty, the Andaman and Nicobar Islands present a landscape of scenic picturesque extravaganza, shining like an emerald in the Bay of Bengal. People from all the states in India live on these islands in harmony with their own cultures. The natural beauty of The Andaman and Nicobar Islands is very attractive. The Andaman Islands offer a wide variety of activities to the travelers like trekking, snorkeling, fishing, scuba diving, deep sea diving, helicopter rides, seaplane rides, water skiing, speed boat rides, surfing, kayaking, sea walking and so on which attract a large number of Adventure Tourists. Natural site attractions are the pristine beaches, thick and dense tropical rainforests, limestone caves and volcanoes are the major attractions for Eco tourists. The novel coronavirus disease was first identified in December 2019 in Wuhan, China. The outbreak has been severely disseminated worldwide, leading the World Health Organisation to declare COVID-19 as a pandemic on 11th March 2020. COVID-19 has infected over ten million people and caused over 5,00,000 deaths worldwide by June 2020 (WHO, 2020). The pandemic has triggered severe social and economic disruption around the world. As a result of COVID-19, movement restrictions, curfews, and travel bans were executed by governments across the world to tackle the pandemic. Thus, most of the states have closed their borders to tourists. Businesses faced closures, travel, and tourism sectors suffered, and unemployment rates rose. According to the study, the number of tourist arrivals in these islands during 2021 decreased to 123180 compared to 196619 in 2020. This is due to the impact of COVID-19 on the tourism industry, as a result, the tourist inflow rate declined.

REVIEW OF LITERATURE

Chand et al., (2021) studied the Impact of Covid-19 on tourism-based livelihood of people in Andaman and Nicobar Island in India. According to the study, tourist arrivals in Andaman and Nicobar Island have decreased as a result of the Covid-19 pandemic, causing serious consequences for the island's livelihood and traditional economic sectors, such as coconut farming and fisheries, which are in serious decline; the region urgently requires economic reforms. The study also demonstrates that the tourist industry would face more obstacles in the future in order to return to its pre-pandemic state. The study concludes that structural, logistical, and human resource development techniques can mitigate Covid-19's negative effects, and that the government should give assistance and subsidies to help the industry to recover. **Abbas et al., (2021)** explored the impact of tourism industry at the global level. According to the study, COVID-19 has made a significant impact on the tourist business, making it one of the most harmed industries worldwide. The study also found that the COVID-19 pandemic has a major influence on tourist organizations such as intermediaries, transportation planners, and hotel or attraction providers, depending on factors such as the tourism industry's size, venue, management, and governance types. The travel needs that are very different from leisure and business travel, local and individual tourists are also affected by the COVID-19. The study suggests that the significant amount of money needs be invested in the tourist business in order to restore it to its former status. **Rahman et al (2021)** According to the findings, the Covid19 pandemic has a significant impact on tourists travel risk and attitude of management. The study show that risk management, service delivery, transportation patterns, and distribution channels, avoidance of overcrowded places, and hygiene and safety are all significantly associated with travel risk and management perception. The findings also revealed that travel risk has a moderate influence on management attitude

STATEMENT OF THE PROBLEM

Andaman and Nicobar Islands are excellent destination for adventure and ecotourism. Andaman and Nicobar Islands are a major tourism center in India. It offering wide varieties of adventure and ecotourism activities such as scuba diving, snorkeling, sea walk, trekking, island camping, parasailing, water skiing, sea plane rides, Helicopter rides, Bird watching, Mangrove safari, Trekking, kayaking, Mangrove safari, kayaking, camping, Turtle Nesting and so on. However, tourism is yet to realize its full potential. The state of affairs for tourism is definitely not very positive but Andaman and Nicobar Islands have the potential to make it one of the best offerings in this country. There are some issues that need to be addressed Andaman and Nicobar Islands failed to realize its full potential as a



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tourism hub for India because of infrastructural inadequacies and no proper promotional techniques utilized by the destination marketers. Many of the islands don't have proper communication facilities like internet and poor network coverage. Roads are in bad condition, poor physical infrastructure in places other than Port Blair, connectivity between port Blair and other islands is a major problem. The tourist inflow has been growing but not at the desired rate. The inflow of tourists is 400018 in 2016 and is increased to 487232 in the year 2017 and in the year 2018 it is increased to 513521. By this we can say that the tourist inflow has been growing but not at the desired rate. There are possibilities for these islands to develop much more. Out of total arrivals in the islands, 97 per cent are domestic tourists, whereas only three per cent are foreign tourists based on data of 2018. As per the data of 2016, 96 per cent are domestic tourists, whereas only four per cent are foreign tourists. It is declined to 1 per cent from 2016 to 2018. Foreign tourist's arrivals are very less compared to domestic tourists. This is due to non-availability of international flights. Due to the impact of the Post COVID-19, the tourist inflow declined. The inflow of tourists is 521604 in 2019, 196619 in the year 2020 and is decreased to 123180. By this we can say that the tourists inflow rate declined drastically.

OBJECTIVES

1. To identify effects on tourist inflow due to COVID-19 in A & N Islands.
2. To study month-wise domestic & foreign tourist arrivals in A & N Islands.
3. To deliver certain strategies that will help tourists to cope with challenges shortly soon.
4. To provide suggestions to increase the inflow of tourists in the A & N Islands.

RESEARCH METHODOLOGY

This study has been done on the basis of secondary data. The secondary data was collected through articles, and other related websites. Researcher collected information from Annual report and statistical handbook related to Tourism Industry from Directorate of Tourism Department.

TOURISM IN ANDAMAN AND NICOBAR ISLANDS

The Andaman and Nicobar Islands are a group of Islands located in the Bay of Bengal, off the eastern coast of India. These islands are recognized for their stunning natural beauty, pristine beaches, rich marine life, and unique indigenous cultures. At present, the Islands are popular among tourists for undertaking adventure activities like sea walks, snorkeling, scuba diving, and so on. The Andaman and Nicobar Islands have a tropical climate, and the best time to visit is between October and May when the weather is pleasant and conducive to outdoor activities. Andaman is growing into a main tourism hub in India competing with other states in India like Goa, Kerala, and Tamil Nadu. Tourism brings in a substantial amount of money through tourists' expenditures on accommodations, food, transportation, and recreational activities. Tourism plays a crucial role in the economic growth and development of the Andaman and Nicobar Islands. For the extension of the tourism industry, the destination requires to be marketed effectively by undertaking advanced promotional techniques.

IMPACT OF COVID-19 OUTBREAK ON TOURIST INFLOW IN ANDAMAN AND NICOBAR ISLANDS DURING 2019-2022

The Andaman Islands have experienced an increasing tourist inflow primarily due to its wide-ranging adventure activities. The Islands furnish a range of stimulating experiences such as water sports, scuba diving, snorkeling, trekking, and exploring pristine beaches and dense forests. These Adventure activities attract tourists seeking unique and thrilling experiences, contributing to the growth of the tourism industry in the A & N Islands. The Andaman Islands have gained significant popularity among tourists. The domestic tourism sector in the Andaman Islands has emerged as the largest segment of the tourism industry primarily due to improved air connectivity. The development and expansion of air transportation infrastructure have played a crucial role in facilitating the growth of domestic tourism in the region. However, the absence of international flights has resulted in a dearth of foreign tourists. International flights play a vital role in enabling the arrival of travelers from various countries by providing them



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with convenient and direct access to their desired destinations. Before the onset of the COVID-19 pandemic, the tourist inflow to the Andaman Islands was thriving, but now it has faced numerous limitations and challenges. The table below provides insights into the impact of COVID-19 on tourist inflow to the Andaman Islands. Table 1 gives the number of Domestic Tourist Arrivals, Foreign Tourists Arrivals, and Total Tourist Arrivals in Andaman for the years 2015 to 2022 along with the corresponding growth rate over the previous year. Table 1 suggests that the increase in domestic tourist arrivals has been consistently and significantly higher compared to the growth in foreign tourist arrivals from 2015 to 2018. Between 2018 and 2021, there have been evident fluctuations in both domestic and foreign tourist arrivals. The COVID-19 Pandemic has had a substantial impact, leading to a significant decline in domestic tourist inflow and a corresponding decrease in foreign tourist arrivals. Notably, the decline in foreign tourist arrivals even reached negative figures, while domestic tourist inflow experienced a notable decrease. This is due to the impact of the COVID-19 outbreak on tourist inflow in the Andaman and Nicobar Islands. The COVID-19 pandemic severely affected tourism as travel restrictions, including lockdowns and border closures, greatly hindered domestic and international travel opportunities for tourists. Health concerns and the fear of contracting or spreading the virus discouraged people from undertaking travel. Flight cancellations and reduced flight operations made it difficult for tourists to reach their destinations. Mandatory quarantine made it difficult and expensive for tourists, while the uncertain economy and job losses reduced people's ability to spend on travel. Additionally, the closure of hotels, restaurants, and tourist attractions made it less appealing and inconvenient for tourists to visit. As a result, there was a significant decrease in the number of tourists during the COVID-19 pandemic. The growth rate of domestic tourists from 2016-17 to 2020-21 showed a decline and eventually went into negative territory, with growth rates of 34.66%, 18.16%, 0.06%, 1.75%, and -84.17% respectively. The growth rate of foreign tourists from 2016-17 to 2020-21 experienced fluctuations with figures of 27.56%, -1.54%, 4.27%, -19.58%, and -92.68%. The negative growth rates show that the number of foreign tourists visiting during those years declined, which had a significant impact on foreign tourist inflow. Furthermore, the overall growth rates of total tourists from 2016-17 to 2020-21 were consistently declining and even turned negative, primarily due to the impact of COVID-19.

MONTH-WISE DOMESTIC TOURIST ARRIVAL DURING 2016-2021

Domestic tourism involves individuals enjoying holidays and gateways within their nation. Andaman stands out among other Indian states as a preferred choice for tourists due to its exceptional and distinctive qualities. With enhanced air connectivity, Andaman has witnessed a steady rise in domestic tourist visits. Air connectivity has significantly improved in Port Blair, with regular flights operated by Air India, Jet Airways, Jetlite, Go Air, Indigo, Vistara, and Spice Jet Airlines linking the city to major destinations such as Chennai, Kolkata, New Delhi, Mumbai, and Bhubaneswar.¹ Due to the impact of the COVID-19 pandemic, domestic tourism in Andaman experienced a significant decline. Several factors contributed to this decline, including travel restrictions, lockdown measures, and concerns about health and safety. The imposition of travel bans and the closure of tourist destinations as preventive measures to curb the spread of the virus limited people's ability to travel within the country. Additionally, apprehensions regarding the risks associated with traveling during the pandemic further discouraged domestic tourism. As a result, Table 2 reflects a noticeable decrease in domestic tourist arrivals in Andaman during the period affected by the COVID-19 pandemic. According to Table 2, in May 2017, the number of domestic tourists increased by 40 percent, which is a significant growth. However, if we compare May 2017 to May 2019, the growth rate declined by -8.97 percent. In 2019, the growth rate of domestic tourism showed a negative trend, indicating a decline in comparison to previous years. As we move forward to 2021, the growth rate further decreased and reached zero. The period from May 2019 to 2021 has witnessed a significant impact on domestic tourism. It appears that the major impact on domestic tourism began in May 2019 and continued till 2021. During, the period from April 2020 to October 2020, and continuing into 2021, reveals a zero growth rate in tourism suggesting that the COVID-19 pandemic had a severe impact. The growth rate in domestic tourism declined steadily from 2017 to 2021, with the impact of the COVID-19 pandemic being a major contributing factor. The growth rate went from 22.72 percent in 2017 to 36.46 percent in 2021, reflecting the negative impact of the pandemic on the tourism industry. The Andaman Islands, known for their tourism industry, experienced significant losses in multiple ways. Travel restrictions and lockdown measures imposed to control the spread of the virus greatly affected the inflow of tourists. Hotels, resorts, and other accommodation providers faced a decline in bookings and revenue. The absence of tourists resulted in



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reduced business opportunities for local restaurants, shops, and tour operators. Moreover, the livelihoods of many individuals dependent on the tourism sector were adversely affected. The Andaman Islands, like many other tourist destinations, faced a challenging period due to the impacts of the COVID-19 pandemic.

MONTH-WISE FOREIGN TOURIST ARRIVAL DURING 2016-2021

The tourism industry in Andaman has experienced limitations in attracting foreign tourists primarily due to the absence of adequate international flight connectivity. This lack of direct flights has posed a significant challenge in terms of attracting visitors from other countries. Consequently, Table 3 provides a comprehensive overview of the month-wise foreign tourist arrivals in Andaman from 2016-2021, including the corresponding growth rates compared to the previous year. This data highlights the impact of restricted international access on foreign tourist inflow to the region during the specified period. After the COVID-19 pandemic, foreign tourist arrivals declined significantly due to various reasons such as travel restrictions, border closures, fear of infection, and limited international flight availability. **Source:** Department of Tourism (Andaman and Nicobar Administration) Table 3 indicates that the growth of Foreign Tourist Arrivals (FTAs) in Andaman is underwhelming, as the majority of annual changes from the previous year are not positive. From April 2020 to October 2020, extending into 2021, there was no growth in tourism, indicating a significant negative impact of the COVID-19 pandemic. The maximum growth of FTA took place during December 2021 with 156.14 percent compared to December 2020 (-89.92) which is 2remarkable. The overall analysis of the growth rate from 2017 to 2021 reveals a consistent negative trend, with only minimal improvement in 2019. However, the subsequent years, 2020 and 2021, experienced a significant decline, with negative growth rates observed. This downward trajectory indicates the profound impact of the COVID-19 pandemic on the tourism sector, leading to reduced foreigntourist arrivals and challenging conditions for the industry.

STRATEGIES TO HELP TOURISTS COPE WITH CHALLENGES IN THE NEAR FUTURE

1. Implement enhanced safety measures at tourist facilities.
2. Ensure clear and open communication regarding travel restrictions and guidelines.
3. Provide flexible booking policies to facilitate easy adjustments and cancellations for travellers.
4. Make use of digital solutions to enable contactless transactions and provide virtual experiences for tourists.
5. Encourage sustainable tourism practices to preserve and safeguard the environment.
6. Ensure stringent hygiene standards are maintained and readily available sanitization facilities are provided.
7. Offer dedicated customer support services to ensure prompt assistance and support for tourists.
8. Engage in collaborative efforts with local authorities to establish coordinated responses to overcome challenges effectively.
9. Promote diversification of tourist destinations to mitigate overcrowding and enhance visitor experiences.
10. Demonstrate empathy and flexibility in catering to the needs of tourists, ensuring a personalized and accommodating experience.

FINDINGS OF THE STUDY

1. Between 2018 and 2021, tourist arrivals showed significant fluctuations. The COVID-19 pandemic notably reduced both domestic and foreign tourist inflow, leading to a marked decline in tourism across all sectors.
2. It is found from the study that The growth rate of domestic tourists from 2016-17 to 2020-21 showed a decline and eventually went into negative territory, with growth rates of 34.66%, 18.16%, 0.06%, 1.75%, and -84.17% respectively. The growth rate of foreign tourists from 2016-17 to 2020-21 experienced fluctuations with figures of 27.56%, -1.54%, 4.27%, -19.58%, and -92.68%. The negative growth rates show that the number of foreign tourists visiting during those years declined, which had a significant impact on foreign tourist inflow.
3. The analysis of growth rates from 2017 to 2021 shows a steady negative trend, with a slight improvement in 2019. However, the years 2020 and 2021 saw a sharp decline, reflecting the severe impact of the COVID-19 pandemic on the tourism sector, resulting in fewer foreign tourist arrivals and challenging industry conditions.
4. The growth of Foreign Tourist Arrivals (FTAs) in Andaman has been disappointing, with most annual changes showing negative trends. From April 2020 to October 2020, continuing into 2021, tourism saw no growth, highlighting the severe negative impact of the COVID-19 pandemic.





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SUGGESTIONS TO ENHANCE TOURIST INFLOW IN THE A & N ISLANDS

1. If International flights are introduced to the Andaman Islands, more foreign tourists would likely come through routes in Singapore and Thailand.
2. The Andaman tourism sector ought to work towards nurturing cruise tourism. If international cruise companies choose the islands as a destination, it could bring significant advantages to the region.
3. Andaman is well-positioned to host a range of both national and international water sports activities, serving as a platform awareness about the Islands.
4. The ships and ferry boats in Andaman are not in good condition. It's important to ensure proper maintenance and cleanliness for a enjoyable experience for tourists. Moreover, consideration should be given to replacing the older vessels with newer ones.
5. The Andaman restaurant scene is currently limited in its offerings. To better serve the majority of tourists who prefer dining outside, the industry should actively work on establishing a greater number of restaurants.
6. Tour operators should dedicate specific efforts to enhance the branding and marketing of the Islands' tourism, positioning it as a premier destination in India. This can be achieved through mediums such as brochures and popular social media platforms like Facebook, Twitter, and YouTube.

CONCLUSION

The Andaman and Nicobar Islands comprise a picturesque collection of landmasses situated in the Bay of Bengal. However, the lack of planning and regulation in the development of tourism in the Andamans poses a significant threat to this valuable heritage. It is crucial for the Directorate of Tourism, AN Administration, the inhabitants of this captivating archipelago, and the Tour Operators to take courageous and definitive actions, demonstrating leadership to prevent this potential harm. The islands possess considerable tourism potential, and if visitors choose the islands as their destination, it could lead to substantial benefits for the region. In addition to boosting tourism on the islands, it has the potential to bring economic prosperity to the local communities.

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Table 1: Tourist Inflow in the Andaman and Nicobar Islands

YEAR	DOMESTIC TOURIST		FOREIGN TOURIST		TOTAL TOURISTS	
	ARRIVAL	GROWTH(%)	ARRIVAL	GROWTH(%)	ARRIVAL	GROWTH(%)
2015-16	313265(96.15)	0	12553(3.85)	0	325818(100)	0
2016-17	421846(96.34)	34.66	16012(3.66)	27.56	437858(100)	34.39
2017-18	498473(96.93)	18.16	15766(3.07)	-1.54	514239(100)	17.44
2018-19	498784(96.81)	0.06	16439(3.19)	4.27	515223(100)	0.19
2019-20	507528(97.46)	1.75	13221(2.54)	-19.58	520749(100)	1.07
2020-21	80326(98.81)	-84.17	968(1.19)	-92.68	81294(100)	-84.39





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2021-22	82429(98.21)	2.62	1504(1.79)	55.37	83933(100)	3.24
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Source: Directorate of Tourism (Andaman and Nicobar Administration)

Table 2: Month-Wise Domestic Tourist Arrival During 2016-2021

MONTH	DOMESTIC TOURIST ARRIVALS							GROWTH IN PERCENT				
	2016	2017	2018	2019	2020	2021	TOTAL	2017	2018	2019	2020	2021
JANUARY	43659	58940	71771	74279	76643	19420	344712	35	21.77	3.49	3.18	-74.7
FEBRUARY	37204	48365	58286	58010	54963	28092	284920	30	20.51	-0.47	-5.25	-48.9
MARCH	36174	47026	50828	49151	51964	25177	260320	30	8.08	-3.3	5.72	-51.6
APRI	29351	38156	39086	37119	0	0	143712	30	2.44	-5.03	0	0
MAY	26340	36876	38075	34658	0	0	135949	40	3.25	-8.97	0	0
JUNE	18397	24100	24900	24950	0	0	92347	31	3.32	0.2	0	0
JULY	20931	21977	25064	25375	0	0	93347	5	14.05	1.24	0	0
AUGUST	24026	27630	24624	32124	0	1090	109494	15	-10.9	30.46	0	0
SEPTEMBER	21813	25085	22576	20763	0	2925	93162	15	-10	-8.03	0	0
OCTOBER	34005	39105	35366	61257	0	8828	178561	15	-9.56	73.21	0	0
NOVEMBER	37812	41593	44924	35457	1540	16529	177855	10	8	-21.1	-95.66	973.31
DECEMBER	54840	63066	62779	52255	6097	19430	258467	15	-0.46	-16.8	-88.33	218.68
TOTAL	384552	471919	498279	505398	191207	121491	2172846	22.72	5.59	1.43	-62.17	-36.46

Table 3: Month-Wise Foreign Tourist Arrival During 2016-2021

MONTH	FOREIGN TOURIST ARRIVALS							GROWTH IN PERCENT				
	2016	2017	2018	2019	2020	2021	TOTAL	2017	2018	2019	2020	2021
JANUARY	1700	2290	2317	2327	1983	82	10699	34.91	1.18	0.43	-14.78	-95.86
FEBRUARY	2623	2254	2456	2446	1980	187	11946	-14.07	8.96	-0.41	-19.05	-90.56
MARCH	1667	1992	2216	3363	1188	438	10864	19.5	11.24	51.76	-64.67	-63.13
APRIL	918	1702	1262	1212	0	96	5190	85.4	25.85	-3.96	-100	0
MAY	332	452	434	414	0	0	1632	36.14	-3.98	4.61	-100	0
JUNE	152	312	313	605	0	0	1382	-105.26	0.32	93.29	0	0
JULY	340	415	463	407	0	3	1628	22.06	11.57	-12.1	0	0
AUGUST	581	737	907	816	0	9	3050	26.85	23.07	-10.03	0	0
SEPTEMBER	600	736	777	615	0	85	2813	22.67	5.57	-20.85	0	0
OCTOBER	1511	1156	869	1161	0	172	4869	23.49	-24.83	33.6	0	0
NOVEMBER	2381	1353	1457	1144	90	179	6604	-43.18	7.69	-21.48	-92.13	98.89
DECEMBER	2661	1914	1771	1696	171	438	8651	-28.07	-7.47	-4.23	-89.92	156.14





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TOTAL	15466	15313	15242	16206	5412	1689	69328	-0.99	-0.46	6.32	-66.60	-68.79
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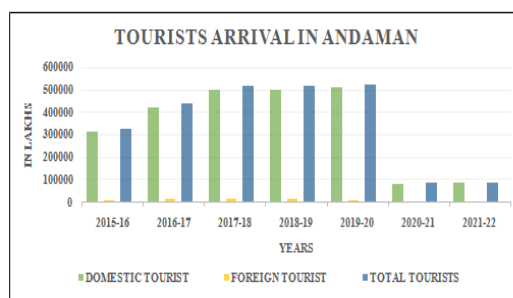


Fig:1

PERCENTAGE SHARE OF MONTHS FOR DTAs IN ANDAMAN, 2016-2021

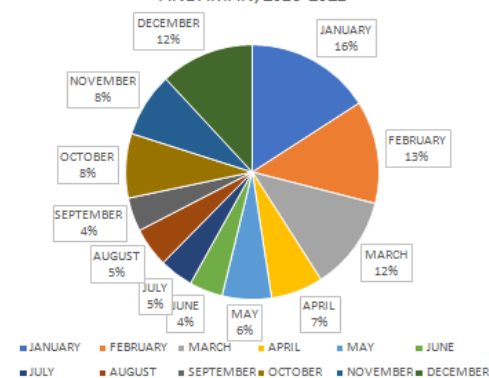


Fig:2

PERCENTAGE SHARE OF MONTHS FOR FTAs IN ANDAMAN, 2016-2021

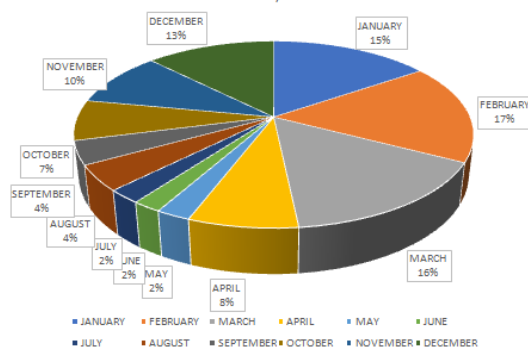


Fig:3





A Comprehensive Review on Medicinal Plants : Current Knowledge and Future Perspectives

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ABSTRACT

Medicinal plants have been utilized for centuries in traditional medicine systems to treat various ailments and promote overall well-being. The natural compounds present in these plants have therapeutic potential and have attracted significant attention from researchers, healthcare professionals, and the general public. This review article aims to provide a comprehensive overview of medicinal plants, highlighting their traditional uses, photochemical composition, Pharmacological Activities and Therapeutic Applications, potential therapeutic applications and Extraction and Standardization Techniques. Furthermore, it discusses recent advancements in research, challenges, and future perspectives in the field of medicinal plants.

Keywords: Medicinal plants, traditional medicine, photochemical, therapeutic applications, natural products, traditional uses, scientific research, challenges, future perspectives

INTRODUCTION

The analysis of medicinal plants dates back to ancient civilizations, where traditional healers and herbalists relied on empirical knowledge and observation to identify plants with therapeutic potential. This knowledge was often passed down through generations, and medicinal plant usage became an integral part of cultural practices. As scientific advancements took place, new techniques emerged to study medicinal plants more comprehensively. In the 19th and



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early 20th centuries, chemical extraction methods, such as maceration and percolation, were developed to isolate active compounds from plants. These techniques laid the foundation for modern phytochemical analysis. The transmission of empirical knowledge about the beneficial effects of various practices, substances, or activities within human communities has been a fundamental aspect of cultural evolution [1]. Indeed, natural products have played a crucial role in the development of drugs, and many modern pharmaceuticals have their roots in traditional herbal medicine [2]. The use of plants in medicine has a long and rich history that dates back to ancient times, and this practice continues to be significant in modern times [3]. Absolutely, the trial and error method played a fundamental role in the early development of medicinal practices [4]. Indeed, the development of medicine based on plants has been a common thread across diverse civilizations throughout history. Each civilization, shaped by its unique environment, cultural practices, and available flora, contributed to the rich tapestry of traditional herbal medicine. [5, 6]. Indeed, the transmitted knowledge about the use of plants for medicinal and pharmaceutical purposes is considered by many as the origin of medicine and pharmacy [7]. Many authors reviewed focuses on the recent various important challenges in quality evaluation of medicinal plants in the authenticity, efficacy, toxicity and consistency [8, 9, 10]. Medicinal plants have been used for centuries in various cultures around the world to treat and prevent diseases. The analysis of medicinal plants has evolved over time, incorporating complex techniques to better understand their chemical composition, therapeutic properties, and potential applications. In this discussion, we will explore the Significance of Medicinal Plants in Traditional Medicine and regional aspects of emergent complex techniques used in the analysis of medicinal plants.

Significance of Medicinal Plants in Traditional Medicine

Medicinal plants have played a significant role in traditional medicine for centuries. They are a fundamental component of various traditional healing systems and have been used by different cultures worldwide to treat and prevent diseases. The significance of medicinal plants in traditional medicine can be understood through the following points:

1. **Historical and cultural heritage:** Traditional medicine systems, such as Ayurveda, Traditional Chinese Medicine (TCM), and Indigenous healing practices, have a rich history that dates back thousands of years. Medicinal plants have been integral to these systems and represent the accumulated knowledge and wisdom of generations of healers and practitioners.
2. **Primary source of medicine:** In many traditional medicine systems, medicinal plants are the primary source of medicine. Various parts of the plants, including leaves, flowers, roots, bark, and seeds, are used to prepare remedies. Traditional healers have identified specific plants and their active compounds that exhibit therapeutic properties and have developed methods to extract and administer them effectively.
3. **Wide range of health benefits:** Medicinal plants offer a wide range of health benefits and have been used to address numerous ailments. They can be used for treating common ailments like cold, cough, digestive disorders, and skin conditions, as well as more complex conditions such as cardiovascular diseases, diabetes, and cancer. Traditional medicine systems emphasize the holistic approach to healing, taking into account the physical, mental, and spiritual aspects of health.
4. **Natural and sustainable healthcare:** Medicinal plants provide a natural and sustainable approach to healthcare. They are renewable resources that can be cultivated, harvested, and processed without causing significant harm to the environment. Traditional healers have developed knowledge about plant conservation, cultivation practices, and the appropriate times for harvesting to ensure the sustainability of medicinal plant populations.
5. **Source of new drugs:** Many modern pharmaceutical drugs have their origins in medicinal plants used in traditional medicine. Scientists and researchers often turn to traditional healing systems and their associated plants to discover and develop new drugs. The chemical compounds found in medicinal plants serve as valuable leads for drug development and have contributed to the creation of essential medications.
6. **Cultural relevance and accessibility:** Medicinal plants are deeply rooted in cultural practices and beliefs. They hold significant cultural and spiritual value for communities that have relied on traditional medicine for generations. Traditional healing practices using medicinal plants are often more accessible and affordable to communities with limited access to modern healthcare facilities and expensive pharmaceutical drugs.



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7. Preservation of traditional knowledge: Traditional medicine systems rely on the knowledge and wisdom passed down through generations. The use of medicinal plants in traditional medicine helps preserve this knowledge, as it is often transmitted orally or through apprenticeships. By recognizing and valuing the significance of medicinal plants, traditional medicine practices can continue to thrive and contribute to the overall well-being of communities.

Regional Perspectives

The analysis of medicinal plants also varies across regions due to the diversity of plant species, cultural practices, and traditional knowledge. Different regions may focus on specific techniques or have unique approaches to studying medicinal plants. For example, in traditional Chinese medicine (TCM), a system that has been practiced for thousands of years, a combination of techniques is used. This includes macroscopic examination, organoleptic evaluation (taste, smell, etc.), microscopy, TLC, and HPLC for quality control and authentication of medicinal plant materials. In Ayurveda, an ancient Indian system of medicine, the analysis of medicinal plants involves a holistic approach. It considers not only the chemical constituents but also the energetics, tastes, and post-digestive effects of the plants to determine their therapeutic properties. In various indigenous cultures, traditional knowledge passed down through generations forms the basis for identifying and analyzing medicinal plants. Techniques such as organoleptic evaluation, ethnobotanical surveys, and indigenous knowledge interviews are used to understand the medicinal properties and applications of plants. For example, India is currently having 8000 medicinal plants species according to the Botanical Survey of India (BSI). Details of medicinal plants found in the country are given in figure 1: In Indian medicine system, the medicinal plant species are arranged under the six systems namely Ayurveda, Siddha, Unani, Homeopathy, Sowa-Rigpa and Folk. The numbers of species for each medicinal system are given in figure 2. As per the medicinal plants database taken from National Medicinal Plants Board, Government of India, Figure 3 shows state wise medicinal plants species produced.

Emergent Complex Techniques

In recent decades, with advancements in technology and scientific understanding, complex techniques have emerged for the analysis of medicinal plants. These techniques aim to provide a more detailed and holistic understanding of the chemical composition and therapeutic potential of plants. Let's explore some of these techniques:

1. Chromatography: Chromatographic techniques, such as thin-layer chromatography (TLC), gas chromatography (GC), and high-performance liquid chromatography (HPLC), are widely used to separate and identify chemical constituents of medicinal plants. These techniques allow the identification and quantification of specific compounds present in complex plant extracts.
2. Mass Spectrometry: Mass spectrometry (MS) is a powerful analytical technique that works in conjunction with chromatography. It helps in the identification and structural elucidation of individual compounds present in medicinal plants. Gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS) are commonly employed in plant analysis.
3. Nuclear Magnetic Resonance Spectroscopy: Nuclear magnetic resonance (NMR) spectroscopy is a non-destructive technique used to analyze the structure and chemical properties of organic compounds. It can provide detailed information about the molecular structure, configuration, and interactions of compounds found in medicinal plants.
4. Metabolomics: Metabolomics involves the comprehensive analysis of small molecules, known as metabolites, within a biological sample. It provides a snapshot of the metabolic state of an organism or tissue. Metabolomics techniques, such as liquid chromatography-mass spectrometry (LC-MS) and nuclear magnetic resonance (NMR) spectroscopy, are increasingly used to study the chemical composition and metabolic pathways of medicinal plants.

In summary, the analysis of medicinal plants has evolved over time, incorporating complex techniques to better understand their chemical composition and therapeutic potential. Chromatography, mass spectrometry, NMR spectroscopy, and metabolomics are among the emergent complex techniques used. The regional perspectives of medicinal plant analysis vary, influenced by traditional practices, cultural knowledge, and specific regional approaches



**Jyoti Arora et al.,****Phytochemical Composition****Primary and Secondary Metabolites**

Primary metabolites and secondary metabolites are two categories of chemical compounds produced by living organisms, including plants, animals, and microorganisms. These compounds play important roles in various biological processes and have different functions within an organism.

Primary Metabolites: Primary metabolites are essential compounds that are directly involved in the growth, development, and reproduction of an organism. They are synthesized through fundamental metabolic pathways and are required for basic cellular functions. Primary metabolites are typically produced during active growth phases and are found in high concentrations in cells. Examples of primary metabolites include:

- Carbohydrates: Such as glucose, fructose, and starch, which are involved in energy storage and provide a source of carbon for other metabolic processes.
- Proteins: Composed of amino acids, proteins are involved in structural support, enzymatic reactions, and various cellular processes.
- Nucleic acids: DNA and RNA, which are responsible for genetic information storage and transfer.
- Lipids: Including fatty acids, phospholipids, and triglycerides, which are involved in energy storage, cell membrane structure, and signaling.

2. Secondary Metabolites: Secondary metabolites are compounds that are not directly involved in the growth and development of an organism. They are typically produced during specific stages of growth or under certain environmental conditions, such as stress, competition, or defense against predators. Secondary metabolites often have complex chemical structures and diverse biological activities. Secondary metabolites are typically produced in smaller quantities compared to primary metabolites, and their production can be induced or regulated by environmental factors.

Examples of secondary metabolites include:

- Alkaloids: Such as caffeine, nicotine, and morphine, which are often involved in defense mechanisms or have medicinal properties.
- Terpenoids: Including essential oils, steroids, and plant pigments like chlorophyll and carotenoids, which have various roles in plants, such as defense, attraction of pollinators, and protection against UV radiation.
- Phenolics: Such as flavonoids and tannins, which have antioxidant properties and play roles in plant defense and pigmentation.
- Glycosides: Compounds like cardiac glycosides and cyanogenic glycosides, which can have toxic or medicinal properties.

It's important to note that the distinction between primary and secondary metabolites is not always clear-cut, and some compounds can have characteristics of both categories depending on the context and their biological roles.

Pharmacological Activities and Therapeutic Applications:

Pharmacological activities refer to the specific effects that drugs or chemical substances have on the body. These activities can include therapeutic effects, as well as side effects and other interactions with various biological systems. Therapeutic applications, on the other hand, are the specific uses of drugs or substances to treat, prevent, or manage certain diseases or medical conditions.

There are numerous pharmacological activities and therapeutic applications, as the field of medicine encompasses a wide range of conditions and treatments. Here are some examples of common pharmacological activities and therapeutic applications:

1. Analgesic (pain relief): Drugs such as nonsteroidal anti-inflammatory drugs (NSAIDs) and opioids are used to relieve pain associated with various conditions, such as headaches, arthritis, and postoperative pain.
2. Antimicrobial: Antibiotics and antiviral drugs are used to treat infections caused by bacteria, viruses, fungi, or parasites. They can be used to combat bacterial infections, such as urinary tract infections or pneumonia, as well as viral infections like influenza or HIV.



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3. Antidepressant: These drugs are used to treat depression and related mood disorders. Examples include selective serotonin reuptake inhibitors (SSRIs), serotonin-norepinephrine reuptake inhibitors (SNRIs), and tricyclic antidepressants (TCAs).
 4. Antihypertensive: Medications used to lower high blood pressure are called antihypertensives. They include ACE inhibitors, beta-blockers, diuretics, and calcium channel blockers.
 5. Antidiabetic: Drugs such as insulin and oral hypoglycemic agents are used to manage diabetes, a condition characterized by high blood sugar levels. They help regulate blood glucose levels and prevent complications.
 6. Anticoagulant: These drugs help prevent the formation of blood clots and are used in conditions such as deep vein thrombosis, atrial fibrillation, and pulmonary embolism. Examples include warfarin, heparin, and direct oral anticoagulants (DOACs).
 7. Antihistamine: Used to alleviate allergy symptoms by blocking the action of histamine. They are commonly used to treat allergic rhinitis, hives, and itching.
 8. Antipsychotic: Medications used to manage psychosis and psychotic disorders, such as schizophrenia and bipolar disorder. They help control hallucinations, delusions, and other symptoms associated with these conditions.
 9. Immunosuppressant: These drugs are used to suppress the immune system and prevent rejection in organ transplantation or to treat autoimmune disorders such as rheumatoid arthritis or lupus.
 10. Antineoplastic: Also known as chemotherapy, these drugs are used to treat cancer by targeting and killing cancer cells or inhibiting their growth. They can be used alone or in combination with surgery or radiation therapy.
- It's important to note that this is just a small sample of pharmacological activities and therapeutic applications. The specific drug or treatment choice will depend on the condition being treated, the patient's individual characteristics, and other factors. Always consult a healthcare professional for personalized medical advice.

Extraction and Standardization Techniques

Extraction and standardization techniques play a crucial role in the production of herbal medicines derived from medicinal plants. These techniques ensure that the active constituents of the plants are efficiently extracted and that the final product is consistent in terms of quality and potency. Here are some commonly used extraction and standardization techniques:

1. Maceration: This is a simple and traditional method where the plant material is soaked in a solvent (such as water, alcohol, or a mixture of both) for a certain period to allow the active constituents to dissolve. The resulting solution is then filtered and concentrated to obtain the extract.
2. Percolation: Percolation involves the passage of a solvent through a column packed with the plant material. The solvent extracts the active constituents as it percolates through the material. This method allows for efficient extraction and is commonly used for large-scale production.
3. Soxhlet Extraction: Soxhlet extraction is a continuous extraction technique that utilizes a specialized apparatus. The plant material is placed in a thimble, and a solvent repeatedly cycles between a boiling flask and a condenser, extracting the constituents from the material. This method is useful for extracting constituents that are not easily soluble in a solvent.
4. Supercritical Fluid Extraction (SFE): Supercritical fluid extraction employs a supercritical fluid, such as carbon dioxide (CO₂), as the solvent. Under specific temperature and pressure conditions, CO₂ exhibits both liquid and gas properties, making it an effective solvent for extracting various compounds. SFE is preferred for its selectivity and the absence of residual solvents.
5. Steam Distillation: Steam distillation is commonly used to extract essential oils from aromatic plants. Steam is passed through the plant material, vaporizing the essential oil. The steam-oil mixture is then condensed and separated, resulting in the collection of essential oil.

Standardization techniques involve ensuring the consistency and quality of herbal extracts or medicines. Here are a few common methods of standardization:

Marker Compound Analysis: Identification and quantification of specific marker compounds present in the medicinal plant are performed using analytical techniques such as high-performance liquid chromatography (HPLC),



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gas chromatography (GC), or mass spectrometry (MS). The concentration of these marker compounds is used as an indicator of the quality and potency of the extract.

2. Total Phenolic Content: The total phenolic content of a plant extract can be determined using colorimetric assays. Phenolic compounds are known for their antioxidant properties, and the quantification of total phenolic content provides an estimate of the extract's antioxidant potential.

3. Heavy Metal Analysis: Heavy metal contamination in herbal medicines can be a concern. Analytical techniques such as atomic absorption spectroscopy (AAS) or inductively coupled plasma mass spectrometry (ICP-MS) are employed to detect and quantify heavy metals in plant extracts.

4. Microbiological Analysis: Microbial contamination can affect the safety and stability of herbal medicines. Microbiological tests are performed to assess the presence of bacteria, yeast, mold, and other microorganisms in the extracts.

These extraction and standardization techniques help ensure the consistency, quality, and safety of herbal medicines derived from medicinal plants, providing reliable products for therapeutic use. It is important to note that the specific techniques employed may vary depending on the plant species, desired constituents, and intended applications.

Challenges and Future Perspectives

Medicinal plants have been used for thousands of years in various traditional healing systems and continue to play a significant role in modern medicine. However, they also face several challenges and offer various future perspectives.

Challenges

1. Deforestation and Habitat Loss: The increasing demand for medicinal plants has led to over-harvesting and habitat destruction, resulting in the loss of many plant species. Deforestation not only threatens the survival of these plants but also affects the delicate ecosystems they inhabit.

2. Unsustainable Harvesting Practices: Unregulated and unsustainable harvesting practices can deplete wild populations of medicinal plants. Overexploitation can lead to the extinction of certain species and disrupt the ecological balance of the areas where they grow.

3. Quality Control and Standardization: Medicinal plants often contain numerous bioactive compounds that contribute to their therapeutic effects. However, the concentration of these compounds can vary significantly depending on factors such as plant genetics, growing conditions, and processing methods. Ensuring consistent quality and standardization of herbal products poses a challenge in the industry.

4. Lack of Research and Documentation: Despite their historical use, many medicinal plants lack comprehensive scientific studies to validate their efficacy, safety, and appropriate dosage. The lack of robust research and documentation can hinder their integration into modern healthcare systems.

Future Perspectives

1. Conservation and Sustainable Cultivation: Emphasizing the conservation and sustainable cultivation of medicinal plants is crucial for their long-term availability. Initiatives such as cultivating medicinal plants in controlled environments, promoting organic farming practices, and establishing botanical gardens can help preserve endangered species and protect their habitats.

2. Scientific Research and Evidence-Based Medicine: Increased scientific research can provide a deeper understanding of the active compounds present in medicinal plants, their mechanisms of action, and potential interactions with other medications. Rigorous clinical trials and systematic reviews can establish evidence-based guidelines for the safe and effective use of herbal medicines.

3. Integration with Conventional Medicine: Medicinal plants have the potential to complement conventional medicine. Integrating herbal remedies into mainstream healthcare practices can offer more comprehensive treatment options and reduce reliance on synthetic drugs, particularly for chronic conditions where plant-based therapies may have a role to play.

4. Biotechnological Advancements: Advances in biotechnology, including genetic engineering and plant tissue culture techniques, can facilitate the production of specific compounds found in medicinal plants. This may help



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overcome challenges related to variable chemical composition and ensure consistent quality and potency of herbal products.

5. Traditional Knowledge Preservation: Traditional knowledge about medicinal plants, often held by indigenous communities, is a valuable resource. Collaborative efforts that involve indigenous communities in research, cultivation, and sustainable harvesting practices can help preserve their knowledge and ensure the equitable sharing of benefits derived from these plants.

The analysis of medicinal plants has evolved over time, incorporating complex techniques to better understand their chemical composition and therapeutic potential. Chromatography, mass spectrometry, NMR spectroscopy, and metabolomics are among the emergent complex techniques used.

In summary, while medicinal plants face challenges such as deforestation, unsustainable harvesting practices, and the need for quality control, their future perspectives lie in conservation, scientific research, integration with conventional medicine, biotechnological advancements, and the preservation of traditional knowledge. By addressing these challenges and harnessing their potential, medicinal plants can continue to contribute to human health and well-being.

CONCLUSION

This review article provides a comprehensive overview of medicinal plants, their traditional uses, phytochemical composition, and potential therapeutic applications. The growing interest in natural products and the increasing scientific evidence supporting the efficacy of medicinal plants highlight their relevance in modern healthcare. However, further research, standardization, and collaboration between traditional and modern medicine are necessary to harness their full potential. Medicinal plants offer a promising avenue for the development of new drugs and therapeutic interventions, contributing to the advancement of healthcare and the well-being of individuals.

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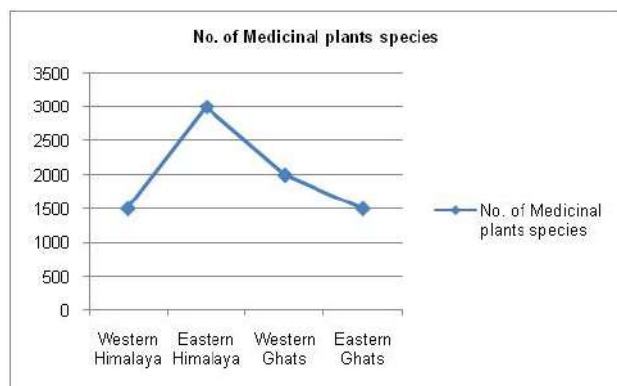


Figure.1: Details of medicinal plants in different parts of India

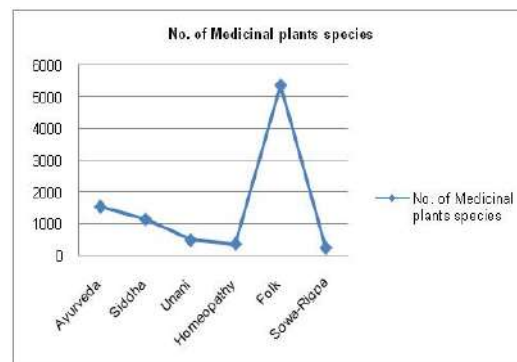


Figure.2: Species of medicinal plants in Indian medicinal system

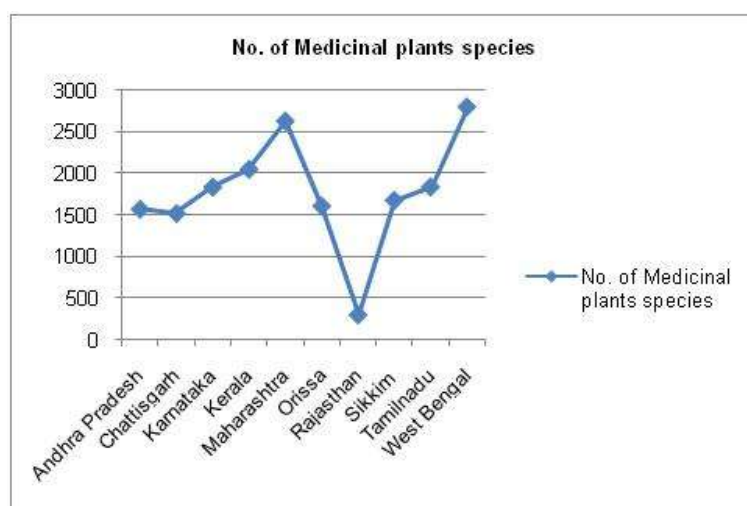


Figure.3: Species of medicinal plants in different states of India





Screening of Potential Bioactive Compounds from *Gymnema sylvestre* and Evaluation of their Binding Affinity with Interleukin Receptor Associated Kinase for Antidiabetic Activity

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ABSTRACT

The potential bioactive compounds from *Gymnema sylvestre* were extracted and analyzed using Gas Chromatography-Mass Spectrometry to identify bioactive molecules with potential therapeutic properties. Subsequent molecular docking studies were performed to evaluate the binding affinity of the identified compounds with interleukin receptor-associated kinase (IRAK), a key receptor involved in various metabolic disorders including diabetes. Among the compound analyzed, n-hexadecanoic acid exhibited a strong binding affinity with IRAK through a combination of hydrogen bonding and hydrophobic interactions suggesting its potential role in modulating the receptor activity. To further validate these findings, the Swiss Target Prediction tool was employed to identify potential biological targets of the phytochemicals, which revealed that the identified compounds interact effectively with receptors implicated in diabetes pathogenesis. These findings support the potential of phytochemicals in *Gymnema sylvestre* as promising antidiabetic agents. Moreover, the insights gained from this study could serve as a foundation for future research exploring the molecular mechanisms underlying the antidiabetic effects of these compounds as well as their potential for development into pharmaceutical or therapeutic applications.

Keywords: Phytochemical Compounds, *Gymnema sylvestre*, Interleukin Receptor Associated Kinase, Hydrogen bonding, Molecular docking, Binding affinity.





INTRODUCTION

Diabetes mellitus, a growing global public health issue, affects millions, particularly in India, due to poor glucose metabolism caused by insulin abnormalities or resistance. Conventional treatments include diet, exercise, and medication, but plant-based remedies like *Gymnema sylvestre* are gaining attention for their anti-diabetic properties, such as reducing sweet taste perception, enhancing glucose absorption, and potentially improving insulin secretion. Other medicinal herbs like cinnamon and bitter melon are also being explored for better glycemic control and reduced complications. *In silico* methods, including molecular docking, are accelerating research into these herbal compounds to develop safer and more effective diabetes therapies. Health supplements are increasingly used to prevent and manage chronic diseases like diabetes, a growing global health concern. Natural supplements such as fenugreek, cinnamon, lipoic acid, and *Gymnema sylvestre* have shown effectiveness in diabetes management. While various supplements offer benefits, *Gymnema sylvestre* stands out as the most accessible and cost-effective option in India (Aamir, 2024). Medicinal plants, used for centuries by various cultures, are reported to benefit diabetes management. As allopathic medicine lacks a completely effective and safe treatment, scientific research has focused on plants like *Gymnema sylvestre*, with findings strongly supporting traditional claims of their effectiveness in treating diabetes and its complications. (Kilambi *et al.*, 2024) Diabetes mellitus, affecting 2.8% of the global population and projected to reach 5.4% by 2025, is a common metabolic disorder. Herbal remedies, increasingly integrated into modern medicine, are valued for their hypoglycemic properties. This review profiles 65 plant species with hypoglycemic activity, categorized by plant parts used, mechanisms (insulin mimetic or secretagogue), and active phytoconstituents. Key plant families include Leguminosae, Lamiaceae, and Cucurbitaceae, with notable species like *Allium sativum*, *Gymnema sylvestre*, *Trigonella foenum-graecum*, and *Momordica charantia*. These plants show significant antidiabetic activity, attributed to polyphenols, flavonoids, terpenoids, and coumarins, often outperforming conventional hypoglycemic agents. (Patel *et al.*, 2022) Plants have long been used as medicine, with traditional Indian medicine relying heavily on botanicals for treating diabetes.

The World Health Organization reports that up to 90% of communities in developing countries use plant-based remedies for primary healthcare. Around 800 plants have antidiabetic properties. It focuses on the antidiabetic potential and bioactive compounds in plants like *Ficus religiosa*, *Pterocarpus marsupium*, *Gymnema sylvestre*, *Allium sativum*, *Eugenia jambolana*, *Momordica charanti* and *Trigonella foenumgraecum*. It serves as a foundation for future research into isolating, purifying, and characterizing these bioactive compounds. (Rizvi and Mishra, 2013) *Gymnema sylvestre*, is a plant species found primarily in the tropical regions of Asia, Africa, and Australia; it is also common in India and Sri Lanka. According to several scientific research, GS includes a chemical element that is known to decrease the desire for sugar; this piqued our interest in investigating the various extracts of GS for its antidiabetic potential (Shanmugam, 2023). *Gymnema sylvestre*, which is utilized in traditional Indian medicine, has demonstrated promising anti-diabetic and hypolipidemic properties. It acts by inhibiting sugar absorption in the intestines and may increase insulin production. Modern synthetic medicines, such as metformin, sulfonylureas, and thiazolidinediones, are routinely used to treat Type 2 diabetes, albeit they can cause weight gain and gastrointestinal problems. *Gymnema sylvestre*, from Asclepiadaceae family known as "gurmar" or "sugar killer," is a prominent herb in Ayurveda. Key phytoconstituents like gymnemic acids, gymnemasaponins, and gurmardin contribute to its sweet-suppression and therapeutic effects. It is widely used to treat diabetes by improving blood sugar homeostasis, reducing sugar cravings, and supporting pancreatic regeneration. Additionally, it is effective for conditions like arthritis, anemia, hypercholesterolemia, cardiopathy, asthma, and microbial infections. The extracts are used in dietary supplements, aids in weight reduction and lowering cholesterol and triglyceride levels, showcasing its potential in both dietary and pharmacological applications (Tiwari *et al.*, 2022). The chemistry and pharmacology of *Gymnema sylvestre* are discussed, and extracts from this plant are frequently utilized in Australian, Japanese, Vietnamese, and Indian folk medicine. *Gymnema* formulations have a significant effect on taste modulation, particularly the suppression of sweet taste sensations. It is used to treat diabetes and as food additives to prevent obesity and cavities. Anti-allergic, antiviral, lipid-lowering, and other actions have been observed. Many technical efforts have been made to hide the harsh taste of *Gymnema* products (Thangavelu *et al.*, 2020).



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Over 1200 plant species have been reported to cure diabetes mellitus globally due to their alleged hypoglycemic properties. *Gymnema sylvestre* is a plant native to India's central and western regions, as well as the tropic zones of Africa and Australia. It is a potent anti-diabetic plant that has been utilized in folk, Ayurvedic, and homeopathic treatments for millennia (Khan *et al.*, 2012). Obesity is linked to various health issues, with around 300 million people affected worldwide. Herbal medicines, known for their low side effects, are increasingly used to treat obesity and diabetes. Gymnemic acid, an active compound from *Gymnema sylvestre* has anti-obesity and antidiabetic effects. It helps reduce body weight, inhibits glucose absorption, and prevents triglyceride buildup in muscles and the liver, as well as fatty acid accumulation in the bloodstream. (Pothuraju *et al.*, 2014) Researchers have been exploring innovative antidiabetic medicines using various chemical compounds and biomolecules. Nanomaterials, known for their small size, biocompatibility, and ability to penetrate cell membranes, are increasingly used in antidiabetic studies. This study investigates the *in vivo* antidiabetic effect of gold nanoparticles synthesized using the antidiabetic herb *Gymnema sylvestre* on albino rats (Karthick *et al.*, 2014). Herbal medications, particularly plant-derived extracts, have been used for centuries to treat Type 2 diabetes mellitus and have the potential to be low-cost and widely available alternatives to conventional pharmaceuticals in impoverished nations. Extracts of *Gymnema sylvestre* contain anti-diabetic properties and have been utilized as traditional medicine in India for millennia. (Romainian *et al.*, 2013) Phytochemical analysis of *Gymnema sylvestre* stem bark methanol extract identified twelve secondary metabolites. Compounds 1-4 and the crude extract exhibited significant inhibitory effects against α -amylase and α -glucosidase enzymes, as well as antioxidant activity by scavenging DPPH radicals and reducing iron levels. *Gymnema sylvestre* is a promising source of bioactive compounds with strong anti-diabetic potential, both *in vitro* and *in silico*.

These findings may contribute to the development of new treatments for diabetes and metabolic disorders (Yves *et al.*, 2024). *Gymnema sylvestre* has expanded from traditional medicine to becoming a significant player in the herbal and pharmaceutical industries due to its rich bioactive compounds. It is a sought-after functional ingredient in herbal formulations, aligning with rising consumer demand for natural, health-enhancing products. The pharmaceutical industry recognizes its therapeutic potential for conditions like diabetes, liver disorders, inflammation, and microbial infections. Molecular docking studies further highlight the binding affinity of gymnemic acids, supporting its role in developing novel therapeutic agents (Vasudeva *et al.*, 2024) *Gymnema sylvestre* extract exhibits strong antioxidant and free radical scavenging properties, helping to reduce oxidative stress. Molecular docking studies, commonly used in drug design, show that compounds from *Gymnema sylvestre* leaves bind effectively to eNOS, with binding energies comparable to agonists. These findings suggest that *Gymnema sylvestre* can not only regulate blood glucose levels but also potentially prevent diabetic complications in the future (Abedulla *et al.*, 2024). *In silico* analysis uses computational tools to study molecular interactions on a large scale, including protein structures in PDB format. By identifying active sites of proteins and ligands, it provides insights into molecular interactions with therapeutic targets. Docking predicts binding affinity between drugs and targets, aiding in hit identification and lead identification during drug discovery. Structure-based drug design relies on the 3D structure of disease-associated receptors to predict binding affinity, calculate glide energy, and identify molecular interactions, making it crucial for modern drug development (Ramanathan, 2017). The bioactive substances that are present in the *Gymnema Sylvestre* are Gymnemic acids, Stigmasterol, Deacylgymnemic acid, Beta-Amyrin acetate, Longispinogenin, and Phytic acid which has the potential antidiabetic activity (Mayyas *et al.*, 2025) Interleukin receptor-associated kinase plays a pivotal role in antidiabetic and antioxidant activity by binding to the receptor exhibiting the highest binding affinity (Pianchou *et al.*, 2025).

MATERIALS AND METHODS

Collection of sample

Gymnema sylvestre leaves were collected from various places of Thanjavur district. The leaves were washed thoroughly under running tap water and dried under shade. They were then finely ground to a powder in an electric bender. The plant sample was subjected to GC-MS.



**Sample Preparation**

About 2.0g of sample was soaked in 100ml ethanol for 24 hours. The extract was filtered through what man no.1 and the filtrate was concentrated to dryness. The extract was diluted with GC ethanol and was injected in to GC-MS.

Preliminary Phytochemical screening

Lyophilized powder was extracted using ethanol and aqueous solvents, followed by solvent evaporation under reduced pressure. The extracts were screened for phytochemicals, revealing a higher number of active ingredients in the aqueous extract. Due to its richness in bioactive compounds, the aqueous extract was selected for the study.

Test for Alkaloids

1ml of test solution shaken with 2N HCL. Aqueous layer formed, decanted and to which one or two drops of Mayer's reagent added.

Test for Steroids

The extract was refluxed with solution of alcoholic potassium hydroxide till complete saponification takes place. The mixture was diluted and extracted with ether. The ether layer was evaporated and the residue was tested for the presence of steroids.

Test for Saponins

1ml of the extracted was treated with 1% lead acetate solution. Formation of white precipitate indicates the presence of saponins.

Test for Flavanoids

Alkaline reagent test To 1ml of the extract, a few drops of dilute sodium hydroxide were added. An intense yellow color was produced in the plant extract, which become colorless on addition of a few drops of dilute acid indicates the presence of flavanoids.

Test for Phenols

A small quantity of the extract was treated with 1% alcoholic ferric chloride solution. Formation of green indicates the presence of phenol.

Test for Sterols

The residue was dissolved in few drops of diluted acetic acid; 3ml of acetic anhydride was added followed by few drops of concentrated H_2SO_4 . Appearance of bluish green color shows the presence of sterol.

Test for Diterpenoids

5mg of the extract was dissolved in 2ml of 0.01% anhydrous stannic chloride in pure thinly chloride. A purple color formed then changed to deep red after few min and indicates the presence of diterpenoids.

GC-MS Analysis

GC-MS analysis was conducted using a GC Clarus 500 Perkin Elmer system with an Elite-5ms capillary column and helium as the carrier gas. The injection volume was 1.0 μL with a split ratio of 10:1, and the temperature ranged from 50°C to 280°C. Mass spectra were recorded at 70 eV with scans from 40 to 600 Da. Compound identification was performed using the NIST library, requiring a $\geq 95\%$ match for confirmation.

In silico analysis

The IRAK sequence was retrieved from NCBI and analyzed using PROSITE to identify receptor binding sites. Log P and Log S values for the ligand were calculated from its SMILES data in PubChem. Molecular structures of n-hexadecanoic acid and the receptor were obtained from PubChem and PDB, respectively. Docking analysis using Hex predicted the binding affinity, and the results were discussed.





RESULTS

Table 1: Analysis of secondary metabolites in the sample. Table 2: Chemical compounds identified in ethanol extract of leaves of *G.sylvestrae* through GC-MS Study. Figure 1: Receptor sequence submitted to Prosite tool. Figure 2: Binding sites are calculated for the receptor. Figure 3: Structure of n-hexadecanoic acid. Figure 4: Ligand n-hexadecanoic acid docked with receptor. Figure 5: Structure of sanitol alcohol. Figure 6: Ligand santoline docked with the receptor. Figure 7: Structure of cyclopropane. Figure 8: Ligand cyclopropane docked with the receptor. Table 3: Binding affinity for the docked models. Table 4: Log P and Log S for the ligands derived from plant sample

DISCUSSION

The plant sample was collected and the secondary metabolites were identified and it was represented in table 1. The secondary metabolites such as alkaloids, steroids, tannins, saponins, phenols, flavonoids and terpenoids were identified. These metabolites are identified using aqueous and ethanol extract. The presence of alkaloids and the absence of steroids were observed in both the extracts. Tannins and saponins are present in aqueous extract whereas it is absent in ethanol extract. The presence of flavanoids was observed in ethanol extract and it is absence in aqueous extract. The presence of phenols and diterpenoids were observed in both the extracts and the terpenoids were absence in aqueous and ethanol extracts. For effective absorption, drugs are expected to be in an aqueous solution at the absorption site (Savjani *et al.*, 2012). The plant sample *Gymnema sylvesterae* was collected and subjected to GCMS study for phytochemical analysis. There are number of phytochemicals were found in the sample and these compounds were consolidated in table 2. Among the phytochemicals, the compound such as n-hexadecanoic acid, alpha sanitol and cyclopropane has highest peak value 9.87, 9.06 and 6.00 respectively. Because of the highest peak values from the GCMS analysis, these ligands are selected for docking with the receptor. Molecular docking is an insilico technique for determining the interaction between receptors and ligands. The docking score or binding energy obtained during docking is thought to be a result of the ligand's binding affinity to the protein target. The protein Interleukin receptor associated kinase is responsible for diabetes mellitus and is thought to function as a receptor for the ligands n-hexadecanoic acid, santoline, and cyclopropane. The binding sites in the receptor are identified to determine the binding affinity while the receptor is docked with the ligand. The sequence of the receptor Interleukin receptor associated kinase can be obtained from a database and the binding site identified utilizing the prosite tool. Figure 1 depicts the sequence of the receptor submitted to the prosite tool. It could assist us predict the target's binding site with the receptor. Figure 2 indicates the number and location of binding sites on the receptor. The Interleukin receptor associated kinase receptor is having three hits including 2 patterns and 1 profile.

The positions of the binding sites in the receptor are 212-521,218-239,336-348. The position 218 and 226 is for NP_BIND and the proton acceptor site is present in the position 340. The ligands n-hexadecanoic acid, santoline and cyclopropane were binds with the receptor through these binding sites. The structure of the receptor was retrieved and displayed in Figure 3. Figure 4 shows that the structure of the ligand n-hexadecanoic acid. The receptor docked with the ligand n-hexadecanoic acid and it was represented in Figure 5. In the present study, docking of potentially active compounds were performed and their binding affinities were predicted. Figure 6 represents that the structure of the ligand sanitol which was retrieved from the database. The receptor docked with the ligand sanitol and it was represented in the Figure 7. Figure 8 shows that the structure of the ligand cyclopropane and it is docked with the receptor. The docked structure for the receptor and ligand was represented in the Figure 9. The observed docking scores were compared and it was very much similar to the previous studies. The docking results demonstrated that the compounds had a high binding affinity and interacted with the active site of the receptor. This strongly suggests that these chemicals may have contributed considerably to the reported hypoglycemic action. The docking parameters include Emax, Emin, Eave, and average energy. The docked structures' binding affinity was anticipated, and the findings were consolidated. The ligand n-hexadecanoic acid, sanitol and cyclopropane is having the binding affinity of 4.21, 1.20 and -1.34 respectively. Among the docked structures, n-hexadecanoic acid had the highest affinity for the receptor interleukin receptor associated kinase. The docking results demonstrated that the compounds



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had a high binding affinity and interacted with the active site of the receptor. This strongly suggests that these chemicals may have contributed considerably to the reported hypoglycemic action. The overall drug-likeness property quantitatively evaluates how closely the physicochemical and structural characteristics of compounds align with those of most well-established drugs (Ononamadu and Ibrahim, 2021). Log P and Log S values for ligands were analyzed using PubChem, with n-hexadecanoic acid showing the highest Log P value (5.21), indicating strong binding affinity and effectiveness against diabetes mellitus. A drug's lipophilicity measures its solubility in lipids or nonpolar solvents, significantly influencing its overall ADMET properties. This characteristic is crucial for drug absorption across cell membranes (Arnott and Planey, 2012). This suggests the potential as a promising therapeutic agent for diabetes, warranting further in vivo and in vitro studies for drug development.

CONCLUSION

Phytochemical compounds from *Gymnema sylvestre* were extracted via GC-MS and docked with the interleukin receptor-associated kinase to evaluate their binding affinity and physicochemical parameters. The ligand n-hexadecanoic acid exhibited strong binding affinity through hydrogen bonding and hydrophobic interactions with the receptor. Swiss target prediction identified potential targets, suggesting that the phytochemicals interact effectively with the receptor responsible for diabetes, supporting their potential as anti-diabetic agents and for further research into their mechanisms and applications. From these observations, it can be concluded that the results may help in understanding the mechanism of the molecule and could be used for further studies in the future.

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Table.1: Analysis of secondary metabolites in the sample

S. No	Test	Aqueous	Ethanol
1	Alkaloids	+	+
2	Steroids	-	-
3	Tannins	+	-
4	Saponins	+	-
5	Flavanoids	-	+
6	Phenols	+	+
7	Terpenoids	-	-
8	Diterpenoids	+	+

Table.2: Chemical compounds identified in ethanol extract of leaves of *G.sylvestrae* through GC-MS Study

S. No.	RT	Name of the compound	MF	MW	Peak area %
1.	4.73	Propane, 1,1-diethoxy-	C ₇ H ₁₆ O ₂	132	1.82
2.	6.05	Catechol	C ₆ H ₆ O ₂	110	4.00





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3.	6.88	3-Methoxyacetophenone	C ₉ H ₁₀ O ₂	150	0.98
4.	9.56	2,3,5,6-Tetrafluoroanisole	C ₇ H ₄ F ₄ O	180	0.89
5.	10.21	1,2,3,4-Cyclohexanetetrol	C ₆ H ₁₂ O ₄	148	1.47
6.	12.49	Tetradecanoic acid	C ₁₄ H ₂₈ O ₂	228	1.92
7.	13.75	Bicyclo[2.2.1]heptane, 1,3,3-trimethyl-	C ₁₀ H ₁₈	138	7.43
8.	14.13	6-Octen-1-ol, 3,7-dimethyl-, formate	C ₁₁ H ₂₀ O ₂	184	2.78
9.	14.48	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-, (1 α ,2 β ,5 α)-	C ₁₀ H ₁₈	138	3.45
10.	16.19	n-Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	9.87
11.	18.56	Isophytol	C ₂₀ H ₄₀ O	296	7.70
12.	19.32	α -Santoline alcohol	C ₁₀ H ₁₈ O	154	9.06
13.	23.40	DL-Ephedrine	C ₁₀ H ₁₅ NO	165	1.81
14.	25.00	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	C ₁₉ H ₃₈ O ₄	330	2.35
15.	25.29	Phthalic acid, di(hept-3-yl) ester	C ₂₂ H ₃₄ O ₄	362	1.31
16.	27.82	Spiro[cyclopropane-1,2'-[6.7]diazabicyclo[3.2.2]non-6-ene]	C ₉ H ₁₄ N ₂	150	6.00
17.	29.47	Squalene	C ₃₀ H ₅₀	410	5.10
18.	30.917	2H-1-Benzopyran-6-ol, 3,4-dihydro-2,8-dimethyl-2-(4,8,12-trimethyltridecyl)-, [2R-[2R*(4R*,8R*)]]-) (δ -Tocopherol)	C ₂₇ H ₄₆ O ₂	402	0.47
19.	31.50	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, [S-(Z)]-(Nerolidol)	C ₁₅ H ₂₆ O	222	0.93
20.	31.96	γ -Tocopherol	C ₂₈ H ₄₈ O ₂	416	1.06
21.	32.18	Cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-yl)-1-vinyl-	C ₁₅ H ₂₄	204	0.94
22.	32.61	1-Docosene	C ₂₂ H ₄₄	308	0.96
23.	32.90	Vitamin E	C ₂₉ H ₅₀ O ₂	430	3.90
24.	33.32	Cholane-5,20(22)-diene-3 β -phenoxo	C ₃₀ H ₄₂ O	418	3.70
25.	33.80	β -Amyrin	C ₃₀ H ₅₀ O	426	3.07
26.	34.06	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-	C ₃₀ H ₅₀ O	426	3.45
27.	34.49	Stigmasterol	C ₂₉ H ₄₈ O	412	5.40
28.	35.48	Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1S-(1 α ,7 α ,8 α)]-	C ₁₅ H ₂₄	204	1.10
29.	36.19	A-Norcholestan-3-one, 5-ethenyl-, (5 β)-	C ₂₈ H ₄₆ O	398	1.61
30.	36.67	Hop-22(29)-en-3 β -ol	C ₃₀ H ₅₀ O	426	1.44
31.	37.27	α -Tocopherol- β -D-mannoside	C ₃₅ H ₆₀ O ₇	592	2.02
32.	38.29	A'-Neogammacer-22(29)-ene	C ₃₀ H ₅₀	410	1.31
33.	39.53	Phytol, acetate	C ₂₂ H ₄₂ O ₂	338	0.33
34.	40.01	Cedrene-V6	C ₁₅ H ₂₄	204	0.34



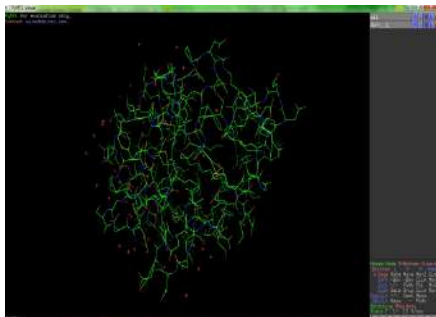


Figure.4: Structure of n-hexadecanoic acid

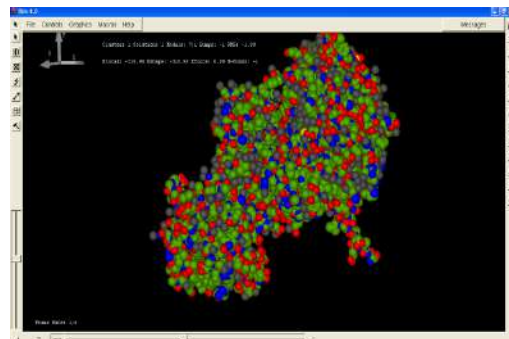


Figure.5: Ligand n-hexadecanoic acid docked with receptor

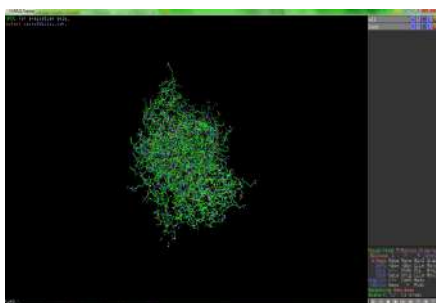


Figure. 6: Structure of santol alcohol

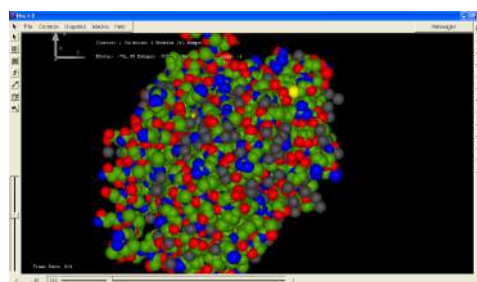


Figure.7: Ligand santoline docked with the receptor

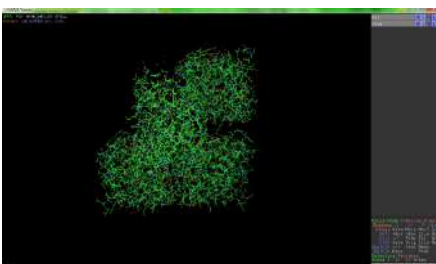


Figure.8: Structure of cyclopropane

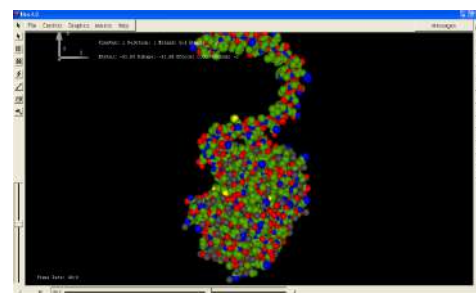


Figure.9: Ligand cyclopropane docked with the receptor





Relay Nodes Selection Algorithm for Clustered Wireless Sensor Network using Fuzzy Logic (RNCWSNFL)

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ABSTRACT

Relay node selection in cooperative wireless sensor networks using fuzzy logic techniques involves intelligently choosing optimal relay nodes to enhance communication efficiency, reliability, and network performance. This approach leverages fuzzy logic principles to handle the inherent uncertainty and imprecision in wireless environments, ensuring more adaptive and effective decision-making for routing and data transmission. The limited energy of relay nodes remains a critical challenge in the design of cooperative communication systems for wireless sensor networks. To address this, we propose a novel relay node selection strategy grounded in fuzzy logic. In our approach, the residual energy of each node and the path loss to the destination node are used as key input parameters for determining the optimal relay. The fuzzy logic rules are designed to prioritize nodes with the lowest path loss and the highest residual energy, ensuring a more efficient and reliable selection process. By simultaneously considering both residual energy and path loss, our strategy achieves a significantly lower Bit Error Rate (BER) compared to existing methods, such as the random selection strategy and the maximum residual energy



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strategy. In the random strategy, relay nodes are selected without consideration, while in the maximum energy strategy, the node with the highest remaining energy is always chosen. Simulation results further demonstrate that our fuzzy logic-based approach strikes a balance between Network Lifespan (NL) and energy consumption. It offers a fair trade-off between the two existing strategies, resulting in extended network longevity and more efficient energy use across the network.

Keywords: wireless sensor network, BER, network Lifespan, network throughput, residual energy.

INTRODUCTION

Wireless sensor networks (WSNs) are extensively utilized across a wide range of applications and services, including industrial automation, mining, healthcare, military operations, agriculture, and home automation [1]. However, communication within these networks often faces challenges due to the unreliability of wireless channels. Factors such as noise, signal fading, interference, reflections, and antenna misalignment can lead to distortion and degraded network performance. To mitigate these issues, several solutions have been proposed, such as cooperative communication, energy harvesting, and the use of multiple antennas. The design and implementation of a WSN must be tailored to the specific requirements of the application in question. In this paper, we focus on achieving reliable communication using cooperative communication techniques. In cooperative communication, an intermediate node, known as a relay node, is employed to regenerate and forward information between the source and destination nodes. This approach serves as an intermediate solution to balance both energy efficiency and throughput, offering a significant improvement in service quality, particularly in scenarios where there is a considerable distance between the source and destination. The role of the relay node is critical in ensuring reliable communication, as it enhances the overall performance of the WSN [2]. In this strategy, neighboring nodes share their antennas to create spatial diversity, allowing them to transmit packets on channels with the best available quality. By leveraging channel knowledge, nodes can transmit their neighbors' data on higher-quality channels, increasing link capacity while avoiding the instability of poor channels. Cluster head and relay selection is a key aspect of this communication strategy and is influenced by the specific constraints of the application [2-5]. A variety of relay selection techniques have been proposed, each designed with a different perspective, but the primary goal remains the same: to reduce the energy consumption at the relay node. Energy constraints are a major concern, as relay nodes often face limitations such as battery depletion or higher energy consumption rates than can be offset by energy harvesting. In this paper, we propose a cooperative communication strategy that utilizes fuzzy logic to select relay nodes. This approach aims to balance energy efficiency and communication reliability.

Related Work

The concept of cooperative diversity, first introduced by Laneman *et al.* [6], was developed to address the challenge of mitigating the detrimental effects of multipath fading in wireless networks. Multipath fading occurs when transmitted signals take multiple paths to the receiver due to reflections, scattering, and diffraction, often resulting in signal degradation and reduced communication reliability. Cooperative diversity leverages the collaboration of multiple nodes, operating across various layers of the network, to enhance signal robustness and improve overall system performance. To address the issue of spectral inefficiency in traditional cooperative diversity techniques, Laneman and Wornell [7] later introduced a space-time architecture. This method offered improved spectral efficiency while still achieving full diversity gain, surpassing previous approaches in performance. One of the major challenges in cooperative relaying schemes is excessive bandwidth utilization. To address this, Laneman *et al.* [8] introduced various relay selection algorithms, including fixed, selective, and incremental relaying techniques. They demonstrated that full diversity can be attained through proper relay selection, which not only enhances spectral efficiency but also reduces system complexity compared to conventional cooperative relaying systems. Building on earlier advancements in relay selection, Bletsas *et al.* [9] enhanced the concept by introducing an innovative best relay selection scheme that dynamically adapts to real-time channel conditions between R_i and the F. This adaptive



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strategy not only improved the efficiency of the relay selection process but also addressed the challenge of optimizing communication paths. A key benefit of this approach was its ability to significantly reduce the number of communication channels required. Specifically, it streamlined the system to rely on just two channels: one direct communication link from the E to the F and another relayed link involving the E-Ri and Ri-F paths. This reduction in channel usage not only simplified system design but also improved spectral efficiency. In subsequent work, Bletsas *et al.* [10] expanded on this idea by introducing a distributed opportunistic relay selection scheme. This method focused on further minimizing cooperation overhead among users in systems employing amplify-and-forward and decode-and-forward relaying protocols. By decentralizing the relay selection process, the scheme effectively reduced the need for extensive coordination and signaling among nodes, thereby enhancing the overall scalability and practicality of cooperative wireless systems. These contributions have been instrumental in advancing the design and efficiency of relay-based communication networks. The adoption of cooperative relaying techniques proves highly beneficial in resource-constrained environments such as wireless sensor networks (WSNs), where optimizing system performance and energy efficiency is paramount. These networks often face significant challenges due to limited energy reserves and the need for reliable communication over long distances. To address these issues, Zarifi *et al.* [11] proposed a relay selection scheme specifically designed for distributed WSNs. Their approach focused on improving the average received signal strength at the F, commonly referred to as the access point, thereby enhancing communication reliability and network coverage.

Building on the need for energy-efficient solutions in cooperative WSNs, Ke *et al.* [12] developed a joint power allocation and relay selection algorithm designed to extend network lifespan. Their method, known as the Minimum Cost Criteria (MIC), employs a graphical optimization approach to identify the most suitable relay node. By balancing energy consumption with performance requirements, the MIC algorithm ensures efficient utilization of limited energy resources. This innovative technique integrates energy pricing to guide power allocation decisions, enabling a more sustainable and cost-effective operation of WSNs. Together, these advancements underscore the critical role of intelligent relay selection and power management in optimizing the functionality and longevity of WSNs in resource-limited settings. Notable advancements in the field also include the contributions of Kaiser *et al.* [13], who introduced a Neuro-Fuzzy-based approach for joint power allocation and relay selection in heterogeneous cooperative WSNs. Their strategy, tailored for systems employing the Amplify-and-Forward (AF) relaying scheme, leveraged the integration of neural networks and fuzzy logic to make intelligent, real-time decisions. This method enhanced the adaptability and efficiency of relay selection, particularly in complex and dynamic network environments. By simultaneously optimizing power allocation, their approach achieved a balance between energy consumption and communication performance, thereby improving the overall system reliability and extending the network's operational lifetime. Similarly, Yang *et al.* [14] proposed an energy-aware relay selection algorithm based on fuzzy logic principles. Their algorithm was designed to dynamically evaluate relay nodes based on multiple criteria, such as residual energy, channel quality, and transmission distance. By incorporating fuzzy logic into the decision-making process, the method addressed the inherent uncertainties in WSN environments, resulting in more robust and efficient relay selection. This approach significantly contributed to prolonging the network lifespan (NS) by ensuring energy-efficient operation, a critical factor for resource-constrained WSNs. Collectively, these contributions highlight the effectiveness of soft computing techniques in optimizing key aspects of cooperative WSN performance. In this research, we propose an analytical model for BER analysis in WSNs using a fuzzy-based relay selection scheme. The model aims to improve overall system performance by taking into account the residual energy of the nodes and the path loss between them. By optimizing relay selection based on these parameters, the proposed scheme enhances both communication reliability and energy efficiency, offering a promising solution for cooperative communication in wireless sensor networks.

Simulation Model

In a cooperative diversity scenario, we consider a network covering an area of 100×100 square meters, consisting of a source node (E), a destination node (F), and a set of relay nodes denoted as $\{R_1, R_2, \dots, R_M\}$, as depicted in Figure 1. In this scenario, the communication links between the E-to-F and R-to-F terminals operate in a half-duplex mode. This means that at any given time, a relay node can either receive data from the E or transmit data to the F, but it cannot





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perform both functions simultaneously. Additionally, We consider a straightforward and practical communication setup where each node in the network is equipped with a single antenna. For the communication initial scenario, the direct communication channel between the E and F is assumed to be heavily corrupted, rendering direct transmission between them impossible. As a result, data transmission relies solely on the cooperative relays. The transmission from the E is split into two distinct phases:

1. Broadcast Phase: In this phase, the E broadcast the signal to all the nodes within its communication range.

2. Relaying Phase: During the second phase, the chosen relay nodes transmit the received signal to the F.

Let x represent a complex-valued data symbol drawn from an M-point constellation, which is derived from the BPSK modulation scheme. The data x is of length $1 \times N$, where N is the packet length. The signal transmitted from the E reaches both the F and R, and the received signal at the F and R can be expressed as follows [15]:

$$Y_{E,F} = \sqrt{P_a} \cdot x \cdot P_{GEF} H_{EF} + \eta_{EF} \quad (1)$$

$$Y_{E,R_i} = \sqrt{P_a} \cdot x \cdot P_{GERi} H_{ERi} + \eta_{ERi} \quad \text{for } i = 1, 2, \dots, n \quad (2)$$

In this cooperative communication model, the broadcast phase allows the source node to send information to multiple relay nodes simultaneously. These relay nodes, in turn, aid in the transmission during the relaying phase by regenerating the signal and forwarding it to the destination. The use of multiple relay nodes introduces spatial diversity, which helps in mitigating the effects of channel fading and improves the overall reliability of the communication system. Since the relays operate in half-duplex mode, the system efficiency is affected by the time division between receiving and transmitting operations. Nonetheless, this setup is effective in overcoming severe channel conditions, particularly when the direct path between the E and F is unavailable or unreliable, as is the case in the simulated scenario. The complexity of the system arises from factors such as relay selection, signal processing, and the dynamic nature of wireless channels. In the simulation, we evaluate the system's performance by examining key metrics such as BER and signal-to-noise ratio (SNR). The use of BPSK modulation ensures simplicity in the modulation process, while the focus on cooperative diversity allows for enhanced communication reliability in environments where direct transmission is impractical. This scenario highlights the importance of relay nodes in maintaining reliable communication links and reducing the adverse effects of corrupted channels. By leveraging cooperative diversity and careful relay selection, the system can achieve robust communication, even in challenging wireless environments. In this cooperative communication scenario, let H_{EF} and P_{GEF} represent the channel coefficient and path gain for the link between the E and F respectively. Similarly, H_{ERi} and P_{GERi} denote the channel coefficient and path gain for the link between the E and a given relay node R_i . Additionally, η_{EF} and η_{ERi} represent the additive white Gaussian noise (AWGN) with zero mean and variance N_0 for the E-to-F and E-to- R_i links, respectively. The total transmits power allocated for the broadcast phase is denoted by P_a . During the broadcast phase, the E transmits data to both the R_i and the F. After receiving the signal, the destination node computes the bit error rate (BER). If errors are detected, the algorithm proceeds to the relaying phase, where a relay node R_i forwards the data to the F. If no errors are detected, the algorithm terminates, assuming successful transmission.

In the relaying phase, the received signal at the destination from the relay node R_i is expressed as:

$$Y_{R_i,F} = \sqrt{P_r} \cdot x \cdot P_{GRiF} H_{R_iF} + \eta_{R_iF}$$

Where H_{RiF} is the channel coefficient between the relay node R_i and the destination node, and η_{RiF} represents the AWGN noise with zero mean and variance N_0 . The term P_r represents the Tx power of the R_i , which is influenced by the distance between the R_i and the F. For the AF cooperative scheme, the R_i amplifies the received signal using an amplification factor β , and the amplified signal is then forwarded to the F. The received signal at the F for the AF scheme is given by:

$$Y_{R_i,F} = \beta \cdot Y_{E,R_i} \cdot P_{GRiF} H_{R_iF} + \eta_{R_iF}$$





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In this equation, Y_{E,R_i} represents the signal received by the R_i from the E , and the R_i amplifies it by the factor β before forwarding it to the F .

To determine the path loss and gain for each R_i , the distance between R_i and F is calculated using the following formula [16]:

$$\text{Dist}_{R_i F} = \sqrt{(X_{R_i} - X_F)^2 + (Y_{R_i} - Y_F)^2}$$

$$\text{Path Loss}(P_L) = 10 \cdot \alpha \cdot \log_{10}(\text{Dist}_{R_i F}) + C$$

$$\text{Path Gain}(P_G) = -(P_L)$$

Here, α is the path loss exponent, and C is a constant accounting for system losses.

In this system, it is assumed that the channel coefficients are known only at the F , not at the E . At the F , the signals received during the broadcast and relaying phases are combined using the Maximal Ratio Combining (MRC) scheme. The combined signal at the F is given by:

$$Y = w_1 * Y_{EF} + w_2 * Y_{R_i F}$$

Where w_1 and w_2 are weighting factors, or link weights, that are computed to maximize the strength of the combined signal. These weights are calculated as:

$$w_1 = \frac{\sqrt{P_a H_{EF}^*}}{N_0} \text{ and } w_2 = \frac{\sqrt{P_r H_{R_i F}^*}}{N_0}$$

Assuming that the average energy of the transmitted symbol x is normalized to unity, the instantaneous SNR at the F using MRC is expressed as:

$$\gamma = \frac{P_a * P_{GEF} * |H_{EF}|^2 + P_r * P_{GRI F} * |H_{R_i F}|^2}{N_0}$$

This equation indicates that the overall SNR at the F is a function of the combined contributions from both the direct link (E to F) and the relayed link (R_i to F), maximizing the overall signal strength and enhancing communication reliability.

Calculation of Residual Energy of the Nodes

The energy consumption of nodes in a WSN is primarily due to three factors: transmission energy, reception energy and sensing energy. The total energy consumed by a node when transmitting data depends on the amount of data being sent and the distance between the E and F . The energy consumption during transmission of x bits of data from node i to another node j is defined by two cases based on the distance between the nodes.

Transmission Energy Consumption

The total transmission energy (E_{te}) required to send x bit data from node i to another node j is given by the following equations, which account for different propagation models [17] depending on the distance between the nodes:

- **Free Space Model (distance (ds) less than threshold distance (ds_0)):** In this case, the energy consumption follows a free-space path loss model, and the energy is proportional to the square of the distance.
- **Multipath Model (ds greater than or equal to ds_0):** For longer distances, the multipath fading model applies, where energy consumption is proportional to the 4th power of the distance.

$$E_{te} = \begin{cases} x \cdot E_{el} + x \cdot \varepsilon_{fs} \cdot ds^2, & \text{if } ds < ds_0 \\ x \cdot E_{el} + x \cdot \varepsilon_{ap} \cdot ds^4, & \text{if } ds \geq ds_0 \end{cases}$$

Where:

- x is the number of bits being transmitted.





- E_{el} is the energy consumed by the electronic components of the node during transmission.
- ϵ_{fs} is the energy dissipated in the free-space model.
- ϵ_{ap} is the energy consumed in the multipath model.

The threshold distance ds_0 determines when the system switches from free-space to multipath propagation and is calculated as:

$$ds_0 = \sqrt{\epsilon_{fs} / \epsilon_{ap}}$$

Reception Energy Consumption

The energy consumption for receiving data is more straightforward, as it only depends on the number of bits received and the energy required by the node's electronic circuitry. The reception energy E_{rec} for receiving x bits of data is given by:

$$E_{rec} = x.E_{el}$$

Total Energy Consumption at the Relay Node:

In a cooperative communication scenario, R_i not only receive data but also forward it to the F. The total energy consumption at the j^{th} relay node includes the energy spent on both receiving and transmitting the data:

$$E_{j,tte} = \begin{cases} x.E_{el} + x.\epsilon_{fs}.ds^2 + x.E_{el}, & \text{if } ds < ds_0 \\ x.E_{el} + x.\epsilon_{ap}.ds^4 + x.E_{el}, & \text{if } ds \geq ds_0 \end{cases}$$

Thus, the total energy consumed at the R_i is the sum of the energy required for receiving and transmitting the data, with the distance between the R_i and the F playing a critical role in determining the transmission energy.

Residual Energy of Relay Node

The residual energy of the j^{th} relay node is the remaining energy after accounting for the total energy consumed during both receiving and forwarding the data. If the initial energy of the relay node is E_0 then the residual energy is given by:

$$E_{re} = E_0 - E_{j,tte}$$

This calculation is crucial in a cooperative communication system where energy efficiency is a key design criterion, especially in wireless sensor networks where nodes have limited battery capacity and are often deployed in environments where recharging or replacing batteries is not feasible. By evaluating the residual energy, it becomes possible to select the most energy-efficient relay nodes for data transmission, thereby extending the overall network lifetime. This energy consumption model provides a framework for understanding how energy is expended in wireless sensor networks, particularly in cooperative communication scenarios involving relay nodes. The model emphasizes the importance of distance between nodes and the choice of propagation models (free-space or multipath) in determining energy usage. Additionally, the residual energy calculation is critical for maintaining network performance over time by enabling intelligent relay node selection based on energy efficiency.

Proposed Relay Selection Scheme

The FIS operates in three primary stages:

Fuzzification

Fuzzification is a crucial step in fuzzy logic systems, where precise numerical input values, known as crisp inputs, are converted into fuzzy sets using predefined membership functions [18]. This transformation allows the system to handle uncertainties and approximate reasoning effectively. In the context of the proposed fuzzy-based relay selection scheme, the input parameters, specifically, the P_L and E_{re} of the nodes are modeled as linguistic variables. These linguistic variables are assigned suitable membership functions that categorize the inputs into degrees of membership across defined fuzzy sets. This process enables the fuzzy logic system to interpret and process the input





parameters in a way that aligns with real-world variability and imprecision. Figure 2 illustrates the FIS framework used the input variables (P_L and E_{re}) and the output variable DoS, which represents the relay selection decision. These functions play a pivotal role in translating the crisp data into fuzzy values, facilitating a more adaptive and intelligent selection of relay nodes in dynamic wireless sensor network environments.

- The input variable P_L is divided into three states: min, mid, and max.
- The input variable E_{re} is classified into three states: less, med, and ample.

The output variable, Degree of Selection (DoS), which indicates the quality of the relay node, is divided into five states: f1, f2, f3, f4, and f5.

Inference

Based on the membership function states for the inputs (P_L and E_{re}), a set of nine fuzzy rules is created, forming the core of the fuzzy system. These rules are presented in Table 1 in which f1 has the highest priority and f5 has lowest priority. Fuzzy logic is particularly beneficial when optimizing multiple, potentially conflicting goals. For instance, if P_L is given the highest priority during relay selection, the system will enhance BER performance, but this comes at the cost of network lifetime. Conversely, prioritizing E_{re} improves NL at the expense of BER performance. The fuzzy logic approach helps strike a balance between these two competing factors. In the context of RNCWSNFL the FIS calculates the combined effect of path loss (P_L) and residual energy ($E_{re}\%$) of each relay node. For each relay, a numerical score, denoted as $f(P_L, E_{re}\%)$, is computed, and the node with the highest score is selected as the relay.

The process of fuzzification maps the linguistic values of the input and output variables to their corresponding fuzzy sets. For example, F1 represents path loss and F2 represents E_{re} for each relay node, where:

$F1 = \{\text{min, mid, max}\}$

$F2 = \{\text{less, med, ample}\}$

These states are then mapped to the output fuzzy set $F = \{f1, f2, f3, f4, f5\}$, using a predefined set of if-then rules. A trapezoidal membership function is employed to describe these linguistic values as follows:

$$\text{trap}(y; A, M_1, M_2, B) = \begin{cases} \frac{y - A}{M_1 - A}, & \text{if } x \in [A, M_1] \\ 1, & \text{if } x \in [M_1, M_2] \\ \frac{B - x}{B - M_2}, & \text{if } x \in [M_2, B] \\ 0, & \text{otherwise,} \end{cases}$$

where A and B define the support, and M1 and M2 define the kernel of the trapezoidal function. Using this function, we can define the fuzzification values for F1 (P_L) and F2 (E_{re}).

$$\text{min} = \text{trap}(F_1; 0, 0, M - M/2, M) \quad \text{mid} = \text{trap}(F_1; M - M/2, M, M, M + M/2)$$

$$\text{max} = \text{trap}(F_1; M, M + M/2, \infty, \infty)$$

$$\text{less} = \text{trap}(F_2; 0, 0, 25, 50)$$

$$\text{med} = \text{trap}(F_2; 25, 50, 50, 75)$$

$$\text{ample} = \text{trap}(F_2; 50, 75, 100, 100)$$

Based on the combination of Y1 and Y2, the degree of membership for $f(P_L, E_{i, \text{residual}}\%)$ is defined within the specified range ($\mu(x) \in [0; 100]$) as follows:

$$f5 = \text{trap}(x; 0, 0, 0, 30), f4 = \text{trap}(x; 10, 30, 30, 50), f3 = \text{trap}(x; 30, 50, 50, 70), f2 = \text{trap}(x; 50, 70, 70, 90),$$

$$f1 = \text{trap}(x; 70, 100, 100, 100)$$

Defuzzification

In the defuzzification stage, the fuzzy set corresponding to the input variables produces a single numerical output. The value of the output depends on the type of membership function.





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The final output of the fuzzy system is determined by computing the center of gravity (CoG) of the output membership function. The formula for CoG is:

$$\text{CoG} = \frac{\sum [y \cdot \mu(y)]}{\sum \mu(y)}$$

RESULT AND DISCUSSION

In this paper, we evaluate the performance of the proposed relay selection scheme by comparing it with two widely used approaches: the random relay selection method and the maximum residual energy-based relay selection algorithm. The simulation environment involves randomly deploying nodes over a 100x100m² area, where the nodes remain fixed after deployment for all three algorithms. The communication between nodes is modeled using a Nakagami fading channel, which effectively captures the multipath fading characteristics commonly observed in wireless environments. Each channel is assumed to include additive white Gaussian noise (AWGN) with a mean of 0 and a variance of 1, representing the random noise component affecting the signal during transmission. This setup ensures a realistic simulation of signal degradation due to channel impairments. All nodes in the network operate in half-duplex mode, meaning they can either transmit or receive data at any given time but cannot perform both functions simultaneously. This mode of operation reflects a practical constraint in most wireless communication systems, helping to simplify the design and reduce hardware complexity. Furthermore, the destination node, often referred to as the sink node, is positioned at a fixed location across all simulation scenarios. This static placement serves as a reference point for evaluating network performance, allowing a consistent framework to analyze the impact of different relay selection strategies and channel conditions on overall system behavior. Table 2 presents the parameters utilized in the simulation.

Bit Error Rate (BER)

The BER represents the probability of errors occurring during data transmission, making it a crucial metric for evaluating channel quality. Figure 3 shows the BER performance as the signal-to-noise ratio (SNR) increases. Since we assume constant noise, an increase in SNR indicates higher transmission power, which consequently lowers the BER. Among the three strategies, the proposed RNCWSNFL scheme demonstrates the lowest BER. This is because, in the proposed approach, P_L is considered a key parameter for relay selection, and minimizing P_L leads to fewer bit errors. In contrast, both the random and maximum residual energy strategies disregard P_L , resulting in higher BER. Specifically, the average BER values at a given SNR from Figure 3 are 12.55×10^{-2} for the Random Node Selection (RNS) strategy, 12.93×10^{-2} for the Residual Energy based Node Selection (RENS) strategy, and 11.05×10^{-2} for the proposed approach, showing the proposed algorithm's superior performance in reducing transmission errors.

Throughput is a crucial performance metric for evaluating the reliability and efficiency of a network. It measures the number of data packets successfully received by the base station over a series of rounds, serving as an indicator of how effectively the network is transmitting data under varying conditions. As the number of rounds increases, throughput provides insights into the network's ability to maintain consistent data delivery. In Figure 4, the comparison between the proposed scheme and the RNS and RENS strategies clearly demonstrates the superior performance of the proposed scheme, highlighting its enhanced efficiency and reliability in network throughput.

Network Lifespan

NL refers to the duration until the first node depletes its energy and dies. In Figure 5, we analyze NL as the number of nodes increases from 5 to 40. For these simulations, each relay node is initialized with 0.5 J of energy and the message length is set to 50 bits. Nodes are randomly deployed within a 100x100m² areas. As the number of nodes increases, the opportunity to select different relay nodes also increases, reducing the average number of transmissions per node and thereby lowering energy consumption. This leads to an overall increase in NL. Among the three strategies, the RENS method yields the longest NL because it minimizes per-node transmissions. The proposed algorithm also achieves a relatively high NL since it factors in the energy levels of nodes during relay





selection. In contrast, the RNS strategy results in the shortest NL due to inefficient node utilization. The average NL for different strategies with a 0.2J energy threshold are as follows:

- Maximum residual energy: 1.7438×10^4 seconds
- Fuzzy logic: 1.1905×10^4 seconds
- Random strategy: 0.5059×10^4 seconds

The distance of relay nodes from the destination also significantly affects network lifetime. Longer distances lead to higher energy consumption. Figure 6 shows NL as the average distance of relay nodes from the destination increases. For this simulation, we randomly generate network topologies with 20 relay nodes and set the energy threshold for node death at 0.2J. As the average distance increases, NL decreases due to higher energy requirements for longer-distance transmissions. The difference in NL between the RENS strategy and the proposed approach becomes negligible as the distance increases, whereas the RNS strategy consistently performs poorly with much shorter network In conclusion, the proposed relay selection algorithm consistently outperforms the RNS and RENS strategies across multiple performance metrics, including BER, network lifetime, and energy efficiency. By incorporating both path loss and residual energy into the relay selection process, the fuzzy logic approach offers a balanced and effective solution for enhancing wireless network performance.

CONCLUSION

Cooperative diversity techniques offer a promising solution to address the challenges of spectrum inefficiency in wireless communication systems. In this paper, we present a novel fuzzy-based relay selection algorithm tailored for cooperative communication. The proposed method leverages two key parameters P_L and E_{re} to compute the DoS for selecting the most suitable relay nodes that will cooperate with the source node during transmission. By utilizing fuzzy logic, the algorithm evaluates these parameters to make intelligent and dynamic relay selections, aiming to strike a balance between minimizing transmission errors and optimizing energy consumption. Unlike traditional relay selection methods that may prioritize either energy efficiency or transmission quality exclusively, our proposed approach integrates both considerations, providing a more holistic and adaptive solution. One of the primary benefits of this approach is its superior performance in terms of BER. Among the strategies evaluated, including RNS and RENS, the RNCWSNFL algorithm consistently achieves the lowest BER. This is largely because the method actively considers P_L , a critical factor that directly affects the signal quality. By selecting relay nodes with lower P_L , the system reduces transmission errors, improving overall communication reliability. Additionally, the proposed algorithm demonstrates an efficient balance between energy consumption and NL. In wireless networks, extending NL is crucial, especially in scenarios where nodes are battery-powered and energy resources are limited. While the RENS strategy may prioritize energy conservation by selecting nodes with higher residual energy, it often overlooks other vital factors, such as the distance to the destination or the quality of the communication link. On the other hand, RNS lacks the strategic planning necessary for efficient resource utilization. Our RNCWSNFL scheme addresses these limitations by incorporating both energy levels and communication quality metrics into the relay selection process. As a result, the algorithm not only conserves energy more effectively than random selection but also outperforms traditional strategies in prolonging NL. It achieves this without sacrificing transmission quality, offering a fair tradeoff between conserving energy and maintaining high-quality, error-free communication.

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Table.1: Fuzzy rules for proposed relay selection scheme

P_L	E_{re}	DoS
<i>min</i>	<i>less</i>	<i>f4</i>
<i>min</i>	<i>med</i>	<i>f2</i>
<i>min</i>	<i>ample</i>	<i>f1</i>
<i>mid</i>	<i>less</i>	<i>f4</i>
<i>mid</i>	<i>med</i>	<i>f3</i>
<i>mid</i>	<i>ample</i>	<i>f2</i>
<i>max</i>	<i>less</i>	<i>f5</i>
<i>max</i>	<i>med</i>	<i>f4</i>
<i>max</i>	<i>ample</i>	<i>f3</i>





Table.2: Simulation parameters

Total Nodes	20,40
Total simulation area of network	100 m*100m
Primarily Energy given to the Nodes	0.5 J
Size of frame or packet	50 bits
Energy consumption in the idle state of the transceiver	50 nJ/bit
Energy consumption for data aggregation or fusion	5nJ/bit/report
Energy used for amplification ϵ_{fs} ($d < d_0$)	10pJ/bit/m ²
Energy used for amplification ϵ_{ap} ($d \geq d_0$)	0.0013pJ/bit/m ⁴
P _L exponent	2
Fading Channel	Nakagami-m fading channel

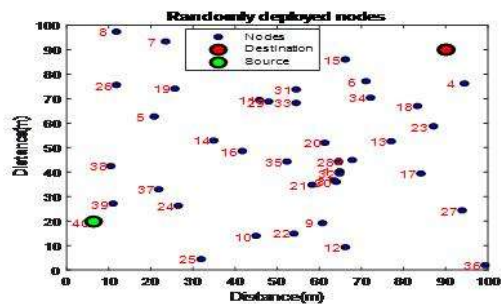


Figure.1:Nodes are randomly deployed across the simulation area

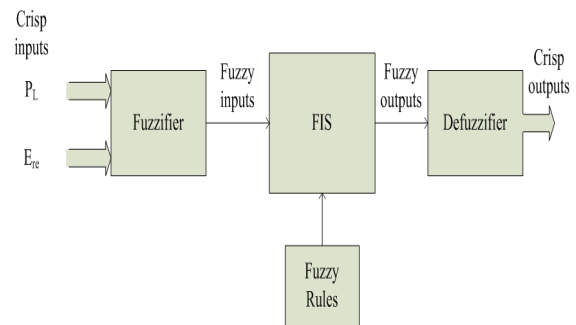


Figure. 2:Fuzzy Inference System (FIS) framework for the proposed relay selection scheme.

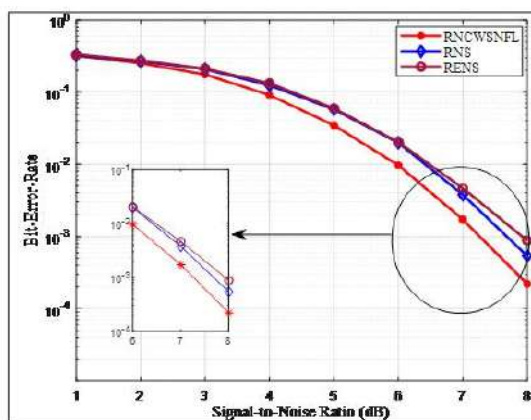


Figure. 3: The BER reduces with an increase in the signal-to-noise ratio (SNR)

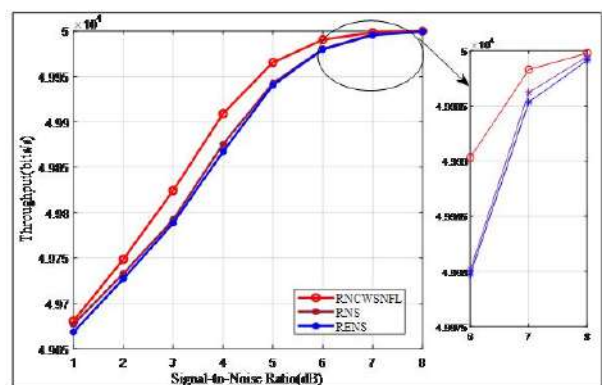


Figure. 4:Network throughput improves as the signal-to-noise ratio (SNR) increases.



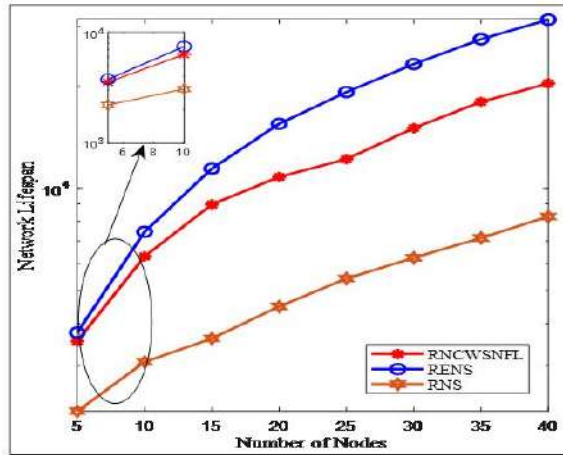


Figure. 5. Network lifespan performance with an increasing number of nodes.

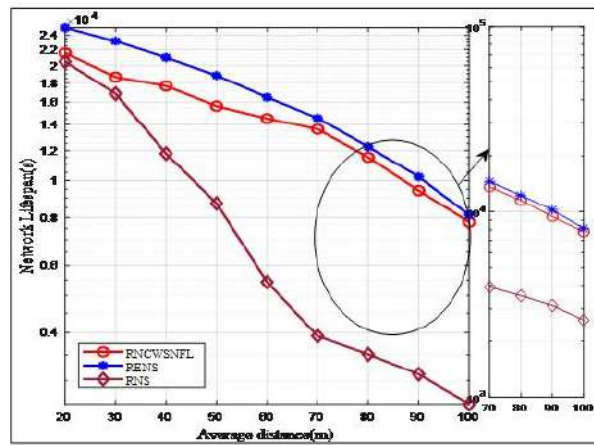


Figure. 6. Performance of network lifespan as the average distance between nodes increases





Customers' Satisfaction towards an Electric Two Wheeler in Tiruchirappalli District

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ABSTRACT

The present study "Customers' satisfaction towards an Electric Two wheeler", was conducted with the aim of determining the socio-demographic characteristics of customers and the various dimensions of customer satisfaction. An attempt was made to find the relationship between selected socio-demographic variables and the various dimensions of customer satisfaction in order to get meaningful inferences.

Descriptive research design was adopted.. The researcher used purposive sampling method for selecting 150 respondents. The information required for the study was directly collected from the customers by giving questionnaire. The data collected through the questionnaire were carefully analysed and processed by using, statistical techniques such as mean, median, t-test, f-test and chi-square analysed Karl Pearson's coefficient correlation. The tests yielded meaningful results. To overcome these deficiencies, suggestions like the improvement of services are to be made.

Keywords: Customer, Electronic Two Wheeler, Service, Product, Satisfaction





INTRODUCTION

Electric two-wheelers have the potential to enhance local air quality and lower greenhouse gas emissions compared to gasoline-powered models. They also offer a reduction in noise pollution, which can make them competitive in the market. However, they face some fundamental performance challenges, such as speed, range, and recharging time. Despite these issues, their lower operating costs can offset some of these performance drawbacks. In India, initial efforts to deploy electric two-wheelers have been hindered by reliability issues, affecting public perception of this emerging technology. The strong preference for gasoline two-wheelers persists, regardless of price or performance differences. To address these challenges, it is crucial for the electric two-wheeler industry, along with government and non-government organizations, to engage in proactive marketing and public awareness campaigns. Additionally, effective policies supporting electric two-wheelers should be paired with advancements in battery manufacturing and infrastructure to foster broader adoption.

Review of Literature

Nigam *et al.* (2023) the study is based on customer satisfaction towards Okinawa Electric bikes. It finishes up the factors affect the customer satisfaction are the brand name, alert and the motor power. More than 90 percent respondents are satisfied with the price of the bike, value for money, mileage and Maintenance. Sangeetha (2023) found that electric bikes are slow but consistently making their way into the two wheeler market. The availability of electric bikes has increased competition in this sector. Environmentally conscious customers recognize the need for pollution reduction. The level of awareness among Electric Bikes users is deemed revolutionary at this time because there is a need to replace the conventional system that pollutes the environment.

Objectives of The Study

- To study the satisfaction levels of customers of electric two-wheeler in Trichy city
- To study the various dimensions of the customer satisfaction
- To find the areas to be improved at the firm as perceived by the customer.
- To suggest suitable measures for improving the existing service. Research Design: Descriptive research design

Sampling : Purposive sampling method

Majority (41.3%) of the respondents are found to be in the age group of 21- 30 years, (23.3%) of the respondents are found to be in the age group of above 40 years, (20.7%) of the respondents are found to be in the age group of 31-40 years and (14.7%) of the respondents are found to be in the age group of up to 20 years. It was found that (26.7%) of the respondents have Rs. 5001-10000, (26%) of the respondents have Rs. up to 5000, (26%) of the respondents have no income and (21.3%) of the respondents have income above Rs. 10000. It was found that (42.7%) of the respondents are business people, (24.7%) of the respondents are students, (24%) of the respondents are professionals, (8.7%) of the respondents are in service. It was found that (71.3%) of the respondents service their bike in authorized service center and (28.7%) of the respondents service their bike in local mechanic shop. It was found that (89.3%) of the respondents maintain their bike as per maintenance schedule and (10.7%) of the respondents didn't maintain their bike as per maintenance schedule. Majority (56%) of the respondents perceive high level of product satisfaction and (44%) of the respondents perceive low level of product satisfaction. (50.7%) of the respondents perceive high level of service satisfaction and (49.3%) of the respondents perceive low level of service satisfaction. (52%) of the respondents perceive high level of overall customer satisfaction and (48%) of the respondents perceive low level of over all customer satisfaction. The above table that there is no significant difference between the type of family (Joint and Nuclear) with regard to the customer satisfaction in the dimensions of difference product satisfaction and service satisfaction. The above table that there is no significant difference between the marital status (Married and Unmarried) with regard to the customer satisfaction in the dimensions of product satisfaction and service satisfaction. It is evident from the above table that there is no significant difference among the various occupation of the respondents with regards to the various dimensions of customer satisfaction namely, product and service satisfaction.



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It is evident from the above table that there is no significant difference among the various area of living of the respondents with regard to various dimensions of customer satisfaction namely products and service satisfaction. The above table that there is a significant association between clear explanation of features respondents and various dimensions of customer satisfaction namely product and service satisfaction.

- Majority 36.7% of the Respondents Suggest power is very good.
- Majority 36.7% of the Respondents Suggest Mileage is good.
- Majority 40.0% of the Respondents Suggest safety is good
- Majority 32.7% of the Respondents Suggest Braking is very good.
- Majority 36% of the Respondents Suggest Riding comfort is very good.
- Majority 33.3% of the Respondents Suggest Road grip is very good.
- Majority 40.7% of the Respondents Suggest Technology is very good.
- Majority 39.3% of the Respondents Suggest pick-up acceleration is very good.
- Majority 47.3% of the Respondents Suggest Availability of spares is very good
- Majority 46.7% of the Respondents Suggest Cost maintenance is good .
- Majority 35.3% of the Respondents Suggest Warranty is very good
- Majority 40.0% of the Respondents Suggest showroom reception is very good.
- Majority 38.0% of the Respondents Suggest timely delivery of service is good.
- Majority 40.0% of the Respondents Suggest Ambience of showroom is very good .
- Majority 41.3% of the Respondents Suggest turnout of staff is good.
- Majority 37.3% of the Respondents Suggest cost of spares is Average.
- Majority 38.0% of the Respondents Suggest Comprehension of customer is very good
- Majority 40.0% of the Respondents Suggest ease of finance option is good.
- Majority 38.0% of the Respondents Suggest Relationship with the customer is very good

There is a significant relationship among various dimensions of customers satisfaction namely product and service satisfaction.

Suggestions

Timely delivery of serviced vehicle may be affected in order to enhance customer satisfaction levels. Customer feedback reveals that serviced vehicles delivered are not delivered in a clean condition. This area needs to be addressed appropriately. Customer feedback reveals that defective performances of vehicle (if any) are rectified if and only if the customers bring these to the notice of service personnel. Service personnel need to diagnose defects even without customer information. This practice would enhance the trust and confidence in the service quality and satisfaction levels of the customers.

CONCLUSION

The conclusion of the study is nearly half of the respondents were satisfied with the product satisfaction and half of the respondents were satisfied with the service satisfaction.

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Table No.1: Distribution Of Respondents By Their Age

S. No.	Age	No. of Respondents (n :150)	Percentage
1	Up to 20 years	22	14.7
2	21 – 30 years	62	41.3
3	31 – 40 years	31	20.7
4	Above 40 years	35	23.3

Table No.2: Distribution of Respondents By Their Income

S. No.	Income	No. of Respondents (n :150)	Percentage
1	No Income Upto Rs. 5000	39	26.0
2	Rs. 5000	39	26.0
3	Rs. 5001 – 10000	40	26.7
4	Above Rs. 10000	32	21.3

Table No. 3: Distribution of Respondents By Their Occupation

S. No.	Occupation	No. of Respondents (n :150)	Percentage
1	Business	64	42.7
2	Professional	36	24.0
3	Student	37	24.7
4	Service	13	8.7

Table No.4: Distribution of Respondents By Where Do You Service

S. No.	Service	No. of Respondents (n:150)	Percentage
1	Authorized Service Center Local	107	71.3
2	Mechanic	43	28.7

Table No.5: Distribution of Respondents By Where Do You Service

S. No.	Service	No. of Respondents (n :150)	Percentage
1	Authorized Service Centre Local	107	71.3
2	Mechanic	43	28.7

Table No.6: Distribution of Respondents By Maintain Your Bike As Per Maintenance Schedule

S. No.	Maintenance as per Schedule	No. of Respondents (n :150)	Percentage
1	Yes	134	89.3
2	No	16	10.7





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Table No.7: Distribution of Respondents By Various Dimensions Of Customer Satisfaction

S. No.	Various Dimensions of Customer Satisfaction	No. of Respondents (n : 150)	Percentage
	Product Satisfaction		
1	Low	66	44.0
	High	84	56.0
2	Service Satisfaction		
	Low	74	49.3
	High	76	50.7
3	Overall Satisfaction		
	Low	72	48.0
	High	78	52.0

Table No.8: 't' Test Between The Respondents Type of Family With Regard To Various Dimensions of Customer Satisfaction

S. No	Type of Family	\bar{x}	S.D.	Statistical Inference
1	Product Satisfaction			t =0.304
	Joint Family	42.822	7.380	P>0.05
	Nuclear Family	42.454	7.167	Not Significant
2	Service Satisfaction			t =1.223
	Joint Family	37.000	6.675	P>0.05
	Nuclear Family	35.625	6.928	Not Significant
3	Overall Satisfaction			t =0.833
	Joint Family	79.822	12.947	P>0.05
	Nuclear Family	78.079	12.156	Not Significant

Table No.09: 't' Test Between The Respondents Marital Status With Regard To Various Dimensions Of Customer Satisfaction

S. No	Marital Status	\bar{x}	S.D.	Statistical Inference
1	Product Satisfaction			t =0.871
	Married	43.086	6.845	P > 0.05
	Unmarried	42.043	7.678	Not Significant
2	Service Satisfaction			t =0.209
	Married	36.086	7.307	P > 0.05
	Unmarried	36.318	6.288	Not Significant
3	Overall Satisfaction			t =0.395
	Married	79.172	12.349	P > 0.05
	Unmarried	78.362	12.699	Not Significant

Table No.10: One Way Analysis of Variance Among Various Occupation of The Respondents With Regard To Various Dimensions of Customer Satisfaction

S. No.	Source	Df	SS	MS	\bar{X}	Statistical Inference
1	Product Satisfaction					
	Between Groups	3	111.324	37.108	G1=42.937	F = 0.705
					G2=41.722	P > 0.05
					G3=43.540	Not Significant
	Within Groups	146	7686.46	52.647	G4=40.769	





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2	Service Satisfaction					
	Between Groups	3	193.795	64.598	G1=37.171	F = 1.393
					G2=34.611	P > 0.05
					G3=36.621	Not Significant
	Within Groups	146	6769.59	46.367	G4=34.538	
3	Overall Satisfaction					
	Between Groups	3	555.969	185.323	G1=80.109	F = 1.195
					G2=76.333	P > 0.05
					G3=80.162	Not Significant
	Within Groups	146	22636.0	155.041	G4=75.307	

G1 = Business G2 = Professional G3 = Student G4 = Service

Table No.11:One-Way Analysis of Variance Among Various Area of Living of The Respondents With Regard To Various Dimensions of Customer Satisfaction

S. No.	Source	Df	SS	MS	X	Statistical Inference
1	Product Satisfaction					
	Between Groups	2	225.947	112.973	G1=43.086	F = 2.193
					G2=42.980	P > 0.05
	Within Groups	147	7571.84	51.509	G3=39.176	Not Significant
2	Service Satisfaction					
	Between Groups	2	78.000	39.000	G1=36.444	F = 0.833
					G2=36.461	P > 0.05
	Within Groups	147	6885.39	46.839	G3=34.176	Not Significant
3	Overall Satisfaction					
	Between Groups	2	569.118	284.559	G1=79.530	F = 1.849
					G2=79.442	P > 0.05
	Within Groups	147	22622.8	153.897	G3=73.352	Not Significant

G1 = Urban G2 = Semi urban G3 = Rural

Table No.12:Association Between Clear Explanation Of Features To The Respondents And Various Dimensions Of Customer Satisfaction

S. No.	The Feature of the Bike Explained	Various Dimensions of Customer Satisfaction		Statistical Inference
		Low	High	
1	Product Satisfaction	n:66	n:84	X ² =9.805 df=1
	Yes	36	66	P<0.01
	No	30	18	Significant
2	Service Satisfaction	n:74	n:76	X ² =8.485 df=1
	Yes	42	60	P<0.01





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	No	32	16	Significant
3	Overall Satisfaction	n:72	n:78	$X^2=5.946$ df=1
	Yes	42	60	P<0.01
	No	30	18	Significant

Table No.13:Distribution of Respondents By Their Level of Satisfaction Towards Product

S. No.	Particulars	No. of Respondents (%)				
		Excellent	Very Good	Good	Average	Poor`
1	Power	30 (20.0)	55 (36.7)	51 (34.0)	10 (6.7)	4 (2.7)
2	Mileage	29 (19.3)	50 (33.3)	55 (36.7)	16 (10.7)	0
3	Safety	26 (17.3)	47 (31.3)	60 (40.0)	13 (8.7)	4 (2.7)
4	Braking	22 (14.7)	49 (32.7)	46 (30.7)	27 (18.0)	6 (4.0)
5	Riding Comfort	26 (17.3)	54 (36.0)	49 (32.7)	16 (10.7)	5 (3.3)
6	Road Grip	21 (14.0)	50 (33.3)	42 (28.0)	30 (20.0)	7 (4.7)
7	Technology	27 (18.0)	61 (40.7)	43 (28.7)	16 (10.7)	3 (2.0)
8	Pick up / Acceleration	15 (10.0)	59 (39.3)	58 (38.7)	15 (10.0)	3 (2.0)
9	Appearance	40 (26.7)	59 (39.3)	39 (26.0)	10 (6.7)	2 (1.3)
10	Design	48 (32.0)	56 (37.3)	35 (23.3)	9 (6.0)	2 (1.3)
11	Product Knowledge of Demo Staff	22 (14.7)	38 (25.3)	56 (37.3)	24 (16.0)	10 (6.7)
12	Overall Performance	23 (15.3)	49 (32.7)	62 (41.3)	16 (10.7)	0

Table No.14:Distribution of Respondents By Their Level Of Satisfaction Towards Service

S. No.	Particulars	No. of Respondents (%)				
		Excellent	Very Good	Good	Average	Poor`
1	Availability of spares	20 (13.3)	71 (47.3)	48 (32.0)	7 (4.7)	4 (2.7)
2	Cost of maintenance	10 (6.7)	30 (20.0)	70 (46.7)	35 (23.3)	5 (3.3)
3	Warranty	16 (10.7)	53 (35.3)	52 (34.7)	20 (13.3)	9 (6.0)
4	Showroom reception	20 (13.3)	60 (40.0)	39 (26.0)	24 (16.0)	7 (4.7)
5	Timely Delivery of Serviced	27 (18.0)	39 (26.0)	57 (38.0)	20 (13.3)	7 (4.7)





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6	Ambience of Showroom	15 (10.0)	60 (40.0)	40 (26.7)	27 (18.0)	8 (5.3)
7	Turnout of Staff	10 (6.7)	43 (28.7)	62 (41.3)	29 (19.3)	6 (4.0)
8	Cost of Spares	9 (6.0)	29 (19.3)	51 (34.0)	56 (37.3)	5 (3.3)
9	Comprehension of customer	19 (12.7)	57 (38.0)	44 (29.3)	21 (14.0)	9 (6.0)
10	Ease of finance option	14 (9.3)	49 (32.7)	60 (40.0)	23 (15.3)	4 (2.7)
11	Relationship with the customer	19 (12.7)	57 (38.0)	46 (30.7)	19 (12.7)	9 (6.0)

Table No.15: Inter Correlation Matrix Among Various Dimensions Of Customer Satisfaction

Dimensions	Product Satisfaction	Service Satisfaction	Overall Satisfaction
Product Satisfaction	1.000		
Service Satisfaction	0.572**	1.000	
Overall Satisfaction	0.893**	0.880**	1.000

** 0.01 Level of Significance





Tree Hop Domination in Connected Graphs

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ABSTRACT

Let $G = (V, E)$ be a connected graph. A subset D of V is called a dominating set of G if $N[D] = V$. The minimum cardinality of a dominating set of G is called the domination number of G and is denoted by $\gamma(G)$. A set $D \subseteq V(G)$ of a connected graph G is a tree hop dominating set of G , if for every v in $V(G) - D$, there exists $u \in D$ such that $d(u, v) = 2$ and $\langle D \rangle$ is a tree. The minimum cardinality of a tree hop dominating set is called tree hop domination number and is denoted by $\gamma_{th}(G)$. In this paper, tree hop number is found for some particular graphs and bounds of tree hop domination number are obtained.

Keywords: Domination number, hop domination number, tree domination number.

Mathematics Subject Classification: 05C69

INTRODUCTION

The graphs considered here are nontrivial, finite and undirected. The order and size of G are denoted by n and m

respectively. If $D \subseteq V$, then $N(D) = \bigcup_{v \in D} N(v)$ and $N[D] = N(D) \cup D$ where $N(v)$ is the set of vertices of G which are adjacent to v . The concept of domination in graphs was introduced by Ore[6]. A subset D of V is called a dominating set of G if $N[D] = V$. The minimum cardinality of a dominating set of G is called the domination number of G and is denoted by $\gamma(G)$. Xuegang Chen, Liang Sun and Alice McRae [7] introduced the concept of tree domination in graphs. A dominating set D of G is called a tree dominating set, if the induced subgraph $\langle D \rangle$ is a tree. The minimum cardinality of a tree dominating set of G is called the tree domination number of G and is denoted by





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$\gamma_{tr}(G)$. S. K. Ayyaswamy et al. [1, 2] defined a new domination parameter called hop domination number of a graph. A set $D \subseteq V(G)$ of a connected graph G is a hop dominating set of G , if for every v in $V(G) - D$, there exists $u \in D$ such that $d(u, v) = 2$. The minimum cardinality of a hop dominating set is called hop domination number and is denoted by $\gamma_h(G)$.

The Cartesian product of two graphs G_1 and G_2 is the graph, denoted by $G_1 \times G_2$ with $V(G_1 \times G_2) = V(G_1) \times V(G_2)$ (where \times denotes the Cartesian product of sets) and two vertices $u = (u_1, u_2)$ and $v = (v_1, v_2)$ in $V(G_1 \times G_2)$ are adjacent in $G_1 \times G_2$ whenever $[u_1 = v_1 \text{ and } (u_2, v_2) \in E(G_2)]$ or $[u_2 = v_2 \text{ and } (u_1, v_1) \in E(G_1)]$. In this paper, tree hop number is found for some particular graphs and bounds of tree hop domination number are obtained.

2. TREE HOP DOMINATION IN SOME CONNECTED GRAPHS

In this section, tree hop domination number is defined and this number is found for some particular graphs.

Definition 2.1: A set $D \subseteq V(G)$ of a connected graph G is a tree hop dominating set of G , if for every $v \in V(G) - D$, there exists $u \in D$ such that $d(u, v) = 2$ and $\langle D \rangle$ is a tree. The minimum cardinality of a tree hop dominating set is called tree hop domination number and is denoted by $\gamma_{th}(G)$.

The tree hop domination number does not exist for some graphs. If this number does not exist for a given connected graph G , then $\gamma_{th}(G)$ is defined to be zero. A tree hop dominating set with cardinality $\gamma_{th}(G)$ is referred as a γ_{th} -set.

Example 2.1.1

In the graph G given in Figure 2.1, minimum tree hop dominating set is $\{v_6, v_7, v_8\}$ and $\gamma_{th}(G) = 3$.

Example 2.1.2

For the graphs given in Figure 2.2, tree hop dominating sets do not exist and $\gamma_{th}(G) = 0$.

Observation 2.1.1

Any tree hop dominating set is a hop dominating set. Therefore, $\gamma_h(G) \leq \gamma_{th}(G)$. This is illustrated by following examples.

Example 2.1.3

In the graph G given in Figure 2.3, the set $\{v_6, v_7\}$ is both a minimum hop dominating set and a minimum tree hop dominating set. Therefore, $\gamma_h(G) = \gamma_{th}(G) = 2$.

Example 2.1.4

In the graph G given in Figure 2.4, minimum hop dominating set is $\{v_5, v_6, v_8, v_9\}$ and $\gamma_h(G) = 4$ and minimum tree hop dominating set is $\{v_5, v_6, v_7, v_8, v_9\}$ and $\gamma_{th}(G) = 5$.

Therefore, $\gamma_h(G) < \gamma_{th}(G)$.

In the following, tree hop domination numbers of some standard graphs are found.

Theorem 2.1.1: For any path P_n on atleast six vertices, $\gamma_{th}(P_n) = n - 4$.

Proof:

Let v_1, v_2, \dots, v_n be the vertices of P_n with v_1 and v_n as pendant vertices and v_2 and v_{n-1} as supports. Let $D = \{v_i \in V(P_n) : d(v_i) = 2 \text{ and } v_i \text{ is not a support}\}$. Then $|D| = n - 4$ and $\langle D \rangle \cong P_{n-4}$. $d(v_1, v_3) = d(v_n, v_{n-2}) = d(v_2, v_4) = d(v_{n-1}, v_{n-3}) = 2$. For each vertex in $V(G) - D$, there exists a vertex in D at distance two. Therefore, D is a tree hop dominating set of G and is minimum and $\gamma_{th}(P_n) = |D| = n - 4$.

Remark 2.1.1:

(i) For $n = 3, 4$ and 5 , $\gamma_{th}(P_n) = 2$.

(ii) For the cycle on atleast six vertices, $\gamma_{th}(C_n) = n - 4$ and for $n = 4, 5$, $\gamma_{th}(C_n) = 2$. $\gamma_{th}(C_3) = 0$.





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Theorem 2.1.2: For the complete bipartite graph $K_{r,s}$, $\gamma_{th}(K_{r,s}) = 2$, where $r, s \geq 2$.

Proof:

Let $[A, B]$ be the bipartition of $K_{r,s}$ and let $u \in A, v \in B$. Then the set $\{u, v\}$ is a tree hop dominating set of $K_{r,s}$. Therefore, $\gamma_{th}(K_{r,s}) \leq 2$. Also $2 = \gamma(K_{r,s}) \leq \gamma_{th}(K_{r,s})$.

Hence, $\gamma_{th}(K_{r,s}) = 2$.

Remark 2.1.2: $\gamma_{th}(K_{1,s}) = 3$, where $s \geq 3$.

Theorem 2.1.3: For the wheel W_n on at least seven vertices, $\gamma_{th}(W_n) = 3$.

Proof:

Let w be the central vertex of W_n and u and v be two vertices of W_n such that $N(u) \cap N(v) = \{w\}$. Then the set $\{u, v, w\}$ is a tree hop dominating set of W_n . Therefore, $\gamma_{th}(W_n) \leq 3$. Also, $3 = \gamma_{th}(W_n) \leq \gamma_{th}(W_n)$ and hence $\gamma_{th}(W_n) = 3$.

Remark 2.1.3:

(i) For $4 \leq n \leq 6$, $\gamma_{th}(W_n) = 0$.

(ii) For $n \geq 3$, $\gamma_{th}(K_n) = 0$.

Theorem 2.1.4: For $n \geq 4$, $\gamma_{th}(P_n \circ K_1) = n - 2$.

Proof:

Let v_1, v_2, \dots, v_n be the vertices of P_n with v_1 and v_n as pendant vertices and let u_i be the pendant vertex adjacent to v_i , $i = 1, 2, \dots, n$. Let $D = V(P_n) - \{v_1, v_n\}$. Then $|D| = n - 2$ and $\langle D \rangle \cong P_{n-2}$. For $i = 1, 2, \dots, n - 2$, $d(u_i, v_{i+1}) = 2$, $d(u_{n-1}, v_{n-2}) = d(u_n, v_{n-1}) = d(v_1, v_2) = d(v_n, v_{n-2}) = 2$. D is a minimum tree hop dominating set of $P_n \circ K_1$.

Therefore, $\gamma_{th}(P_n \circ K_1) = n - 2$.

Remark 2.1.4

(i) $\gamma_{th}(P_3 \circ K_1) = 2$

(ii) For $n \geq 4$, $\gamma_{th}(C_n \circ K_1) = n - 2$, $\gamma_{th}(C_3 \circ K_1) = 3$

Theorem 2.1.5: For $n \geq 4$, $\gamma_{th}(W_n \circ K_1) = 2$

Proof:

Let v be the central vertex of W_n and u be the pendant vertex adjacent to v .

Let $D = \{v, u\}$. Then $\langle D \rangle \cong K_2$. For $v_i \in V(C_{n-1})$, $d(v_i, u) = 2$ and $d(u_i, v) = 2$, where u_i is the pendant vertex adjacent to v_i . Then D is a minimum tree hop dominating set of $W_n \circ K_1$ and hence $\gamma_{th}(W_n \circ K_1) = 2$.

Remark 2.1.5

(i) Since any minimum tree hop dominating set of $K_{r,s}$ is also a minimum tree hop dominating set of $K_{r,s} \circ K_1$, $\gamma_{th}(K_{r,s}) = \gamma_{th}(K_{r,s} \circ K_1) = 2$.

(ii) $\gamma_{th}(K_{1,n} \circ K_1) = 2$, for $n \geq 2$.

Theorem 2.1.6: For $n \geq 6$, let $C_n^{(t)}$ be the one point union of t cycles of length n . Then $\gamma_{th}(C_n^{(t)}) = t(n - 5) + 1$.

Proof:

Let $v, v_i^{(1)}, v_i^{(2)}, \dots, v_i^{(n-1)}$ be the vertices of i th cycle in $C_n^{(t)}$ in order, $i = 1, 2, \dots, t$, where v is the common vertex.

Case 1. n is even

Let $D = \bigcup_{i=1}^t \{v_i^{((n/2)-1)}, v_i^{(n/2)}, v_i^{((n/2)+1)}, v_i^{((n/2)+2)}\}$ and let $D' = (V(C_n^{(t)}) - D) \cup \{v\}$. Then $\langle D' \rangle$ is a tree and is a one point union of t paths of length $((n/2) - 2)$ and t paths of length $((n/2) - 3)$. Also, for any vertex in $(V(C_n^{(t)}) - D')$, $d(v_i^{((n/2)-1)}, v_i^{((n/2)-3)}) = 2$, $d(v_i^{(n/2)}, v_i^{((n/2)-2)}) = d(v_i^{((n/2)+1)}, v_i^{((n/2)+3)}) = d(v_i^{((n/2)+2)}, v_i^{((n/2)+4)}) = 2$. Then D' is a tree hop dominating set of $C_n^{(t)}$ and is minimum. If not, if any vertex of $V(C_n^{(t)}) - D'$ is added with D' , then the hop dominating set will not be a tree.





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Case 2. n is odd

Let $D = \bigcup_{i=1}^t \left\{ v_i \left(\frac{(n-3)}{2} \right), v_i \left(\frac{(n-1)}{2} \right), v_i \left(\frac{(n+1)}{2} \right), v_i \left(\frac{(n+3)}{2} \right) \right\}$ and let $D' = (V(C_n^{(t)}) - D) \cup \{v\}$. $\langle D' \rangle$ is a tree and is the one point union of $2t$ paths of length $((n-5)/2)$ each. Also, $d(v_i((n-3)/2), v_i((n-5)/2)) = d(v_i((n-1)/2), v_i((n-3)/2)) = d(v_i((n+1)/2), v_i((n+3)/2)) = d(v_i((n+3)/2), v_i((n+5)/2)) = 2$. Then D' is a tree hop dominating set of $C_n^{(t)}$ and is minimum.

Therefore, $\gamma_{th}(C_n^{(t)}) = |D'| = t(n-5) + 1, n \geq 6$.

Remark 2.1.6:

$$\gamma_{th}(C_n^{(t)}) = \begin{cases} 2, & \text{if } n = 4, 5 \\ 3, & \text{if } n = 3 \end{cases}$$

In the following, some graphs for which their tree hop domination number is 2 or 3 are given.

Observation 2.1.2:

- (i) If G is a triangular cactus graph T_p whose blocks are p triangles, then $\gamma_{th}(G) = 3$
- (ii) If $J_{m,n}$ is the Jelly Fish graph, then $\gamma_{th}(J_{m,n}) = 2$.
- (iii) For the Durer graph G , $\gamma_{th}(G) = 3$.
- (iv) The Helm graph H_n is the graph obtained from a n -wheel graph by adjoining a pendant edge at each vertex of the cycle. $\gamma_{th}(H_n) = 3$, for $n \geq 6$ and $\gamma_{th}(H_n) = n - 1$, if $n = 3, 4, 5$.
- (v) An (n, k) banana tree $B(n, k)$ is a graph obtained by connecting one leaf of each of n copies of an k -star graph with a single root that is distinct from all stars. Then, $\gamma_{th}(B(n, k)) = n + 1$.
- (vi) An (n, k) firecracker graph $F_{n,k}$ is a graph obtained by the concatenation of nk stars by linking one leaf from each. Then, $\gamma_{th}(F_{n,k}) = n$.
- (vii) The double star $S_{m,n}$ is a graph obtained by attaching m and n pendant edges at each of the pendant vertices of a path. If P_t be the path on t vertices, then $\gamma_{th}(S_{m,n}) = t - 2$, where $t \geq 4$.
- (viii) Let S_m be the star graph. For the Staked Book Graph $B_{n,m} = S_{m+1} \times P_n$, $\gamma_{th}(B_{n,m}) = n - 2$.

Example 2.1.5: Helm graph

In the graph G given in Figure 2.5, minimum tree hop dominating set is $\{v_6, v_7, v_8\}$ and $\gamma_{th}(G) = 3$.

Example 2.1.6: Banana tree

In the graph G given in Figure 2.6, minimum tree hop dominating set is $\{v_6, v_7, v_8\}$ and $\gamma_{th}(G) = 3$.

Example 5.1.7: Firecracker graph

In the graph G given in Figure 2.7, minimum tree hop dominating set is $\{v_1, v_2, v_3\}$ and $\gamma_{th}(G) = 3$.

Theorem 2.1.7: Let G and H be two connected graphs. If $G + H$ is the join of G and H , then $\gamma_{th}(G + H) \leq \min\{\gamma_{tr}(G), \gamma_{tr}(H)\}$.

Proof:

Let D be a minimum tree dominating set of G . Then $\langle D \rangle$ is a tree and D is also a hop dominating set of $G + H$, since for each vertex u in $V(G + H)$, there exists a vertex v in D such that $d(u, v) = 2$. Therefore, $\gamma_{th}(G + H) \leq \min\{\gamma_{tr}(G), \gamma_{tr}(H)\}$.

Theorem 2.1.8: Let G and H be two connected graphs and $|V(G)| = n$ and let D be a tree hop dominating set of G such that $|D| = 2$. If each vertex in $V(G) - D$ is adjacent to exactly one vertex in D , then $\gamma_{th}(G \circ H) = 2$, where $G \circ H$ is the corona of G and H .



**Proof:**

Let D be a tree hop dominating set of a connected graph G such that $|D| = 2$ and each vertex in $V(G) - D$ is adjacent to exactly one vertex in D . Let $D = \{v_1, v_2\} \subseteq V(G)$ and $\langle D \rangle \cong K_2$. Since D is hop dominating set of G , for each vertex u in $V(G) - D$, there exists a vertex v in D such that $d_G(v, u) = 2$. Let vertices of first and second copy of H are adjacent to v_1 and v_2 respectively. Let $u_i^{(1)}, u_i^{(2)}, \dots, u_i^{(m)}$ be the vertices of i^{th} copy of H , $i = 1, 2, \dots, n$. Then $d(u_i^{(1)}, v_2) = d(u_i^{(2)}, v_1) = 2$, for $j = 1, 2, \dots, m$. Since each vertex in $V(G) - D$ is adjacent to exactly one vertex in D , either $d(u_i^{(1)}, v_1) = 2$ (or) $d(u_i^{(2)}, v_2) = 2$, for $i = 3, 4, \dots, n$ and $j = 1, 2, \dots, m$. Therefore, D is tree hop dominating set of $G \circ H$ and D is minimum and hence $\gamma_{\text{th}}(G \circ H) = 2$. In the following, tree hop domination number in Total and Middle graphs of paths, cycles and stars are found.

Observation 2.1.3: For a graph G , any two adjacent vertices of G lie on a triangle in $T(G)$. Therefore, $\gamma_{\text{th}}(T(G)) \geq 3$.

$$\gamma_{\text{th}}(T(P_n)) = \begin{cases} 3, & \text{if } n = 3, 4, 5, 6 \\ n - 4, & \text{if } n \geq 7 \end{cases}$$

Theorem 2.1.9: For the path P_n on n vertices,

Proof:

Let $n \geq 7$ and let S be the set of all supports and pendant vertices of P_n . Then $V(P_n) - S$ is a tree hop dominating set of $T(P_n)$ and is minimum. Therefore, $\gamma_{\text{th}}(P_n) = |V(P_n) - S| = n - 4$. For $n = 3, 4, 5$ and 6 , $\gamma_{\text{th}}(P_n) = 3$.

As in Theorem 5.3.9., the following theorem can be proved.

$$\gamma_{\text{th}}(T(C_n)) = \begin{cases} 0, & \text{if } n = 3 \\ 3, & \text{if } n = 4, 5, 6 \\ n - 3 & \text{if } n \geq 7 \end{cases}$$

Theorem 2.1.10: For the cycle C_n on n vertices,

Theorem 2.1.11: For the star $K_{1,n}$ on $n+1$ vertices, $\gamma_{\text{th}}(T(K_{1,n})) = 3$, if $n \geq 3$.

Proof:

The set containing the central vertex and two vertices of $K_{1,n}$ is a tree hop dominating set of $T(K_{1,n})$ and $\gamma_{\text{th}}(T(K_{1,n})) \leq 3$. Since any two adjacent vertices $T(K_{1,n})$ lie on a triangle, $\gamma_{\text{th}}(T(K_{1,n})) \geq 3$. Therefore, $\gamma_{\text{th}}(T(K_{1,n})) = 3$.

Remark 2.1.7

$$\gamma_{\text{th}}(M(P_n)) = \gamma_{\text{th}}(M(C_n)) = \begin{cases} 2, & \text{if } n = 3 \\ 3, & \text{if } n = 4, 5 \\ n - 3 & \text{if } n \geq 6 \end{cases}$$

(a) $\gamma_{\text{th}}(M(K_{1,n})) = 3, n \geq 3$.

Theorem 2.1.12: Any tree hop dominating set with atleast three vertices of a connected graph G is also a tree hop dominating set of $T(G)$.

Proof:

Let D be a tree hop dominating set of G with $|D| \geq 3$. Then D hop dominates all the vertices of G in $T(G)$.

Remark 2.1.8.

Let G be a graph for which its line graph $L(G)$ is connected. Then any tree hop dominating set with atleast three vertices of $L(G)$ is also a tree hop dominating set of $M(G)$.

2.2. Bounds of Tree Hop Domination Number of Connected Graphs

In this section, bounds of tree hop domination number are obtained and the connected graphs for which the bounds are attained are characterized.



**Observation 2.2.1**

For any connected graph G having n vertices with $\gamma_{th}(G) > 0, 1 \leq \gamma_{th}(G) \leq n - 1$. If $\gamma_{th}(G) = 1$ and if D is a tree hop dominating set of G such that $|D| = 1$, then there exists no vertex u in D such that $d(v, u) = 2$, where $v \in D$. Therefore, $2 \leq \gamma_{th}(G) \leq n - 1$, if $\gamma_{th}(G) > 0$.

Theorem 2.2.1: Let G be a connected graph with at least three vertices. For every subset D of $V(G)$ with atleast two vertices, if either

- (i) there exists at least one vertex in $V(G) - D$ adjacent to all the vertices in D (or)
- (ii) $\langle D \rangle$ contains a cycle or $\langle D \rangle$ is disconnected.

Then $\gamma_{th}(G) = 0$.

Proof

Let D be a subset of $V(G)$ with at least two vertices. If (i) holds, then D is not a hop dominating set of G . If (ii) holds, then D is not a tree dominating set of G .

Therefore, $\gamma_{th}(G) = 0$. In the following, the connected graphs for which $\gamma_{th}(G) = n - 1$ and $n - 2$ are characterized.

Theorem 2.2.2: Let G be a connected graph with n ($n \geq 3$) vertices and $\gamma_{th}(G) > 0$. Then $\gamma_{th}(G) = n - 1$ if and only if G is isomorphic to P_3 .

Proof:

Let D be a tree hop dominating set of G such that $|D| = n - 1$. Then $\langle D \rangle$ is a tree on $(n - 1)$ vertices. Let $u \in V(G) - D$. Let D contains three vertices. Then $\langle D \rangle \cong P_3$ and $|V(G)| \geq 3$. Then u can be adjacent to one or two vertices of P_3 .

In that case, $\gamma_{th}(G) = 2 \neq n - 1$. Also, it can be proved that, if D contains atleast four vertices, then $\gamma_{th}(G) \leq n - 2$. Therefore, D contains exactly two vertices and $|V(G) - D| = 1$ and $\langle D \rangle \cong K_2$. If $G \cong C_3$, then $\gamma_{th}(G) = 0$. Hence, $G \cong P_3$.

Conversely, if $G \cong P_3$, then $\gamma_{th}(G) = 2 = n - 1$.

Theorem 2.2.3: Let G be a connected graph with n ($n \geq 4$) vertices and $\gamma_{th}(G) > 0$. Then $\gamma_{th}(G) = n - 2$ if and only if there exists a tree T in G on $n - 2$ vertices such that each vertex in $V(G) - T$ is adjacent to all the vertices in T other than a pendant vertex in T .

Proof:

Let T be a tree in G on $n - 2$ vertices such that each vertex in $V(G) - T$ is adjacent to all the vertices in T other than a pendant vertex in T . Let $u \in T$. If u is an internal vertex in T , then $T - \{u\}$ is disconnected. Let u be a pendant vertex in T , then $T - \{u\}$ is not a hop dominating set, since there exists a vertex in $V(G) - (T - \{u\})$ adjacent to all the vertices in $T - \{u\}$. Therefore, T is a tree hop dominating set of G and $\gamma_{th}(G) \leq |T| = n - 2$. Since for every vertex w in T , $T - \{w\}$ is not a hop dominating set and $\gamma_{th}(G) \geq n - 2$. Hence, $\gamma_{th}(G) = n - 2$.

Conversely, assume $\gamma_{th}(G) = n - 2$. Let D be a tree hop dominating set of G with $|D| = n - 2$. Then $\langle D \rangle$ is a tree on $n - 2$ vertices. Let $u \in V(G) - D$. If u is adjacent all the vertices in D , then $d(u, v) = 1$, for all $v \in D$. If u is adjacent to at most $n - 2$ vertices of D , then $\gamma_{th}(G) \leq n - 3$. If u is adjacent to all vertices of D other than an internal vertex of $V(\langle D \rangle)$, then $\gamma_{th}(G) \leq n - 3$. Therefore, u is adjacent to all the vertices of D other than a pendant vertex of $\langle D \rangle$.

Theorem 2.2.4: Let G be a connected graph with $\gamma_{th}(G) > 0$, which is self-centered with radius 2. Then $\gamma_{th}(G) = 2$.

Proof:

Choose two adjacent vertices v_1 and v_2 in G such that no vertex of G is adjacent to both v_1 and v_2 . Let $D = \{v_1, v_2\}$. Then $\langle D \rangle \cong K_2$. Since G is self-centered with radius 2, for each vertex w in $V(G) - D$, there exists at least one vertex in D such that $d(w, v_i) = 2$, $i = 1, 2$. Therefore, D is tree hop dominating set of G and $\gamma_{th}(G) \leq |D| = 2$. Since $|D| \geq 2$, $\gamma_{th}(G) = 2$.

Theorem 2.2.5: Let T be a tree of diameter atmost 5. Then $\gamma_{th}(T) = 2$.

Proof:

Let P_n be a longest path of length d in T . Then $d \leq 5$.

Let $d = 5$ and $V(P_5) = \{v_1, v_2, v_3, v_4, v_5, v_6\}$. Then $\{v_3, v_4\}$ is a tree hop dominating set of T . Let $d = 4$ and $V(P_4) = \{v_1, v_2, v_3, v_4, v_5\}$. Then $\{v_3, v_4\}$ is a tree hop dominating set of T . Therefore, $\gamma_{th}(T) = 2$.





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Theorem 2.2.6: Let T be a tree on n vertices such that $\text{diam}(T) = d$. Then $\gamma_{\text{th}}(T) = d - 3$, $d \geq 6$.

Proof:

Let P be a longest path of length d of T , where $d \geq 6$. Let v_1, u_1 be pendant vertices and v_2, u_2 be its supports respectively. Then $V(P) - \{v_1, v_2, u_1, u_2\}$ is a tree hop dominating set of T . Therefore, $\gamma_{\text{th}}(T) \leq d + 1 - 4 = d - 3$, $d \geq 6$.

Theorem 2.2.7: Let G be a connected graph such that $\gamma_{\text{th}}(G) > 0$ and let u and v be any two adjacent vertices in G . Then $D = \{u, v\}$ is a tree hop dominating set of G if and only if

- (i) for any $w \in V(G) - D$, if $N(w) \cap D$ is non-empty, then w is adjacent to exactly one vertex in D .
- (ii) for any $w \in V(G) - D$, if $N(w) \cap D$ is empty, then either w and u (or) w and v (or) w, u and v have common neighbours in $V(G) - D$.

Proof:

Let $D = \{u, v\}$ be a tree hop dominating set of G . If (i) does not hold, w is adjacent to both u and v . If (ii) does not hold, then $d(w, u) \geq 3$ (or) $d(w, v) \geq 3$. Conversely, assume both (i) and (ii) hold. Let $w \in V(G) - D$ and $N(w) \cap D$ is non-empty. Let w be adjacent to u and not adjacent to v . Then $d(w, v) = 2$. Assume $N(w) \cap D$ is empty. Let w and u have a common neighbor, say x in $V(G) - D$. Then wxu is a geodesic path in G and $d(w, u) = 2$. Since $\langle D \rangle \cong K_2$, D is a tree hop dominating set of G .

Theorem 2.2.8: Let G be a connected graph such that $\gamma_{\text{th}}(G) > 0$. Any tree dominating set D of G having atleast three vertices is a tree hop dominating set of G if and only if no vertex in $V(G) - D$ is adjacent to all the vertices in D and for any vertex w in $V(G) - D$ which is not adjacent to u in D , $N(w) \cap N(u) \cap D$ is non-empty.

Proof:

Let D be a tree dominating set of G with $|D| \geq 3$. Assume D is also a tree hop dominating set of G . If a vertex w in $V(G) - D$ is adjacent to all the vertices in D , there exists no vertex v in D such that $d(w, v) = 2$. Therefore, no vertex in $V(G) - D$ is adjacent to all the vertices in D . If w in $V(G) - D$ is not adjacent to $u \in D$ and $N(w) \cap N(u) \cap D$ is empty, then $d(w, u) \geq 3$. Therefore, D is a tree hop dominating set of G . Conversely, assume no vertex in $V(G) - D$ is adjacent to all the vertices in D and for any vertex $w \in V(G) - D$ which is not adjacent to $u \in D$, $N(w) \cap N(u) \cap D$ is non - empty. Then there exists a vertex $v \in N(w) \cap N(u) \cap D$ and wvu is a geodesic path in G and $d(w, u) = 2$. Since $\langle D \rangle$ is a tree, D is a tree hop dominating set of G .

Theorem 2.2.9: Let G be a graph with radius 2 and let v be a vertex of G of eccentricity 2. If $\langle N(v) \rangle$ is totally disconnected, then $\gamma_{\text{th}}(G) \leq \deg(v) + 1$.

Proof:

Let $v \in V(G)$ be of eccentricity 2. Since $\langle N(v) \rangle$ is totally disconnected, $\langle N(v) \rangle \cong K_{1, \deg(v)}$. Let $D = N[v]$. Then $V(G) - D = N_2(v)$ and each vertex in $V(G) - D$ is at distance 2 from v . Therefore, D is a tree hop dominating set of G and $\gamma_{\text{th}}(G) \leq |D| = \deg(v) + 1$. In the following, tree hop domination numbers of connected cubic graphs are discussed.

Theorem 2.2.10: For all connected cubic graphs on six or eight vertices, $\gamma_{\text{th}}(G) = 2$.

Proof:

Let G be a connected cubic graph on six vertices and let u, v be two adjacent vertices in G . Let $D = \{u, v\}$. From the remaining four vertices, two vertices are adjacent to u and the other two vertices are adjacent to v . Therefore, each vertex in $V(G) - D$ is at distance 2 from u (or) v and hence D is tree hop dominating set of G . Let G be a graph on eight vertices and let $D = \{u, v\}$. Let u_1 and u_2 be adjacent to u and v_1 and v_2 be adjacent to v . Then, $d(u_i, v) = d(v_i, u) = 2$, for $i = 1, 2$. The remaining two vertices say, w_1 and w_2 are adjacent to one of u_i and v_i , $i = 1, 2$. Therefore, either $d(w_i, u) = 2$ (or) $d(w_i, v) = 2$ and hence $\gamma_{\text{th}}(G) = 2$.

2.3. Tree Hop Domination Number of Cartesian Product of Graphs

In this section, tree hop domination numbers of $P_n \times P_m$, $P_n \times C_m$ and $C_3 \times C_m$ are found.

Theorem 2.3.1: For $m \geq 4$, $\gamma_{\text{th}}(P_2 \times P_m) = m - 2$.



**Proof:**

Let $v_i^{(1)}, v_i^{(2)}, \dots, v_i^{(m)}$ be the vertices of i^{th} copy of P_m in $P_2 \times P_m$.

Let $D = \{v_1^{(2)}, v_1^{(3)}, \dots, v_1^{(m-1)}\} \subseteq V(P_2 \times P_m)$. Then, for $i = 1, 2, \dots, m-2$, $d(v_2^{(i)}, v_1^{(i+1)}) = 2$, $d(v_2^{(m-1)}, v_1^{(m-2)}) = d(v_1^{(m)}, v_1^{(m-2)}) = d(v_2^{(m)}, v_1^{(m-1)}) = d(v_1^{(1)}, v_1^{(3)}) = 2$ and $\langle D \rangle \cong P_{m-2}$. Therefore, D is a tree hop dominating set of $P_2 \times P_m$ and is minimum. Hence, $\gamma_{\text{th}}(P_2 \times P_m) = |D| = m-2$.

Example 2.3.1

In the graph $P_2 \times P_7$ given in Figure 2.5, minimum tree hop dominating set is $\{v_{21}, v_{31}, v_{41}, v_{51}, v_{61}\}$ and $\gamma_{\text{th}}(P_2 \times P_7) = 5$.

Theorem 2.3.2:

- (i) $\gamma_{\text{th}}(P_3 \times P_m) = m-2$, for $m \geq 4$.
- (ii) $\gamma_{\text{th}}(P_4 \times P_m) = \gamma_{\text{th}}(P_5 \times P_m) = m$, for $m \geq 6$.

Proof:

Let $v_i^{(1)}, v_i^{(2)}, \dots, v_i^{(m)}$ be the vertices of i^{th} copy of P_m in $P_n \times P_m$, for $n = 3, 4, 5$.

(i) For the graph $P_3 \times P_m$, the set $D_1 = \{v_2^{(2)}, v_2^{(3)}, \dots, v_2^{(m-1)}\}$ is a minimum tree hop dominating set of $P_3 \times P_m$.

Therefore, $\gamma_{\text{th}}(P_3 \times P_m) = |D_1| = m-2$, for $m \geq 4$.

(ii) For the graph $P_4 \times P_m$ and $P_5 \times P_m$, the set $D_2 = \{v_3^{(1)}, v_3^{(2)}, \dots, v_3^{(m)}\}$ is a minimum tree hop dominating set of both the graphs $P_4 \times P_m$ and $P_5 \times P_m$.

Therefore, $\gamma_{\text{th}}(P_4 \times P_m) = \gamma_{\text{th}}(P_5 \times P_m) = |D_2| = m$, for $m \geq 6$.

Remark 2.3.1:

- (i) $\gamma_{\text{th}}(P_2 \times P_3) = 2$
- (ii) $\gamma_{\text{th}}(P_4 \times P_m) = 4$, if $m = 4, 5$.
- (iii) $\gamma_{\text{th}}(P_5 \times P_5) = 5$.

Example 2.3.2:

In the graph $P_3 \times P_5$ given in Figure 2.6, minimum tree hop dominating set is $\{v_{22}, v_{32}, v_{42}\}$ and $\gamma_{\text{th}}(P_3 \times P_5) = 3$.

Theorem 2.3.3: For $m \geq 6$, $\gamma_{\text{th}}(P_6 \times P_m) = 2m$.

Proof:

Let $v_i^{(1)}, v_i^{(2)}, \dots, v_i^{(m)}$ be the vertices of i^{th} copy of P_m in $P_6 \times P_m$. Then the set

$$D = \left(\bigcup_{i=1}^m v_3^{(i)} \right) \cup \left(\bigcup_{i=1}^{m-1} v_5^{(i)} \right) \cup \left(\{v_4^{(i)}\} \right)$$

is a tree hop dominating set of $P_6 \times P_m$. Therefore, $\gamma_{\text{th}}(P_6 \times P_m) \leq |D| = 2m$.

Let D' be a tree hop dominating set of $P_6 \times P_m$. The vertex $v_3^{(i)}$ ($i = 1, 2, \dots, m$) is at distance 2 from $v_1^{(i)}$, $i = 1, 2, \dots, m$. Therefore, these m vertices are to be included in D' . The vertex $v_5^{(i)}$ is at distance 2 from at least one of the vertices $v_3^{(i)}$, $i = 1, 2, \dots, m-1$. These $m-1$ vertices and since $\langle D' \rangle$ is a tree, the vertex $v_4^{(1)}$ is to be included in D' . Therefore, D' must have at least $2m$ vertices and $\gamma_{\text{th}}(P_6 \times P_m) \geq 2m$. Hence, $\gamma_{\text{th}}(P_6 \times P_m) = 2m$.

Theorem 2.3.4: $\gamma_{\text{th}}(P_n \times P_m) = 2m + n - 6$, where $m \geq n$ and $7 \leq n \leq 10$.

Proof:

Let $v_i^{(1)}, v_i^{(2)}, \dots, v_i^{(m)}$ be the vertices of $P_m^{(i)}$ in $P_n \times P_m$.

Then $D = V(P_m^{(3)}) \cup V(P_m^{(m-2)}) \cup \{v_1^{(4)}, v_1^{(5)}, \dots, v_1^{(n-3)}\}$ is a minimum tree hop dominating set of $P_n \times P_m$, for $n = 7, 8, 9, 10$. Therefore, $\gamma_{\text{th}}(P_n \times P_m) = |D| = m + m + n - 6 = 2m + n - 6$. As above, the following can be proved.

Observation 2.3.1:

- (i) $\gamma_{\text{th}}(P_2 \times C_m) = m-2$, for $m \geq 4$ and $\gamma_{\text{th}}(P_2 \times C_3) = 2$.
- (ii) $\gamma_{\text{th}}(P_3 \times C_m) = m-2$, for $m \geq 4$.
- (iii) $\gamma_{\text{th}}(P_4 \times C_m) = m$, for $m \geq 6$, and $\gamma_{\text{th}}(P_4 \times C_m) = 4$, if $m = 4, 5$.





- (iv) $\gamma_{th}(P_5 \times C_m) = m$, for $m \geq 5$.
- (v) $\gamma_{th}(P_6 \times C_m) = 2m$, for $m \geq 6$.
- (vi) $\gamma_{th}(P_n \times C_m) = 2m + n - 6$, for $m \geq n$ and $7 \leq n \leq 10$.
- (vii) $\gamma_{th}(C_3 \times C_m) = m - 2$, for $m \geq 4$.
- (viii) $\gamma_{th}(C_3 \times C_3) = 2$.

Example 2.3.3:

In the graph $P_3 \times C_5$ given in Figure 2.7, minimum tree hop dominating set is $\{v_{22}, v_{32}, v_{42}\}$ and $\gamma_{th}(P_3 \times C_5) = 3$.

2.4. Tree Hop Domination Number and Connectivity of Graphs

In this section, an upper bound for the sum of the tree hop domination number and connectivity of a graph is found and the extremal graphs are obtained.

Theorem 2.4.1: For any connected graph G with n vertices, $\gamma_{th}(G) + \kappa(G) \leq 2n - 3$, $n \geq 3$.

Proof:

By Observation 2.2.1

$$\gamma_{th}(G) + \kappa(G) \leq n - 1 + \delta(G) \leq n - 1 + n - 1 \leq 2n - 2.$$

If $\gamma_{th}(G) + \kappa(G) = 2n - 2$, then the following cases are to be considered.

(i) $\gamma_{th}(G) = n$ and $\kappa(G) = n - 2$.

(ii) $\gamma_{th}(G) = n - 1$ and $\kappa(G) = n - 1$

Since $\gamma_{th}(G) \leq n - 1$ the case (ii) alone be considered. But $\gamma_{th}(G) = n - 1$ if and only if $G \cong P_3$ and $\kappa(P_3) = 1 \neq n - 1$. Therefore, there is no connected graph G with $\gamma_{th}(G) + \kappa(G) = 2n - 2$. Hence, $\gamma_{th}(G) + \kappa(G) \leq 2n - 3$, $n \geq 3$.

Theorem 2.4.2: Let G be a connected graph. Then $\gamma_{th}(G) + \kappa(G) = 2n - 3$ ($n \geq 3$) if and only if $G \cong P_3$.

Proof:

If $G \cong P_3$, then $\gamma_{th}(G) = 2$ and $\kappa(G) = 1$ and hence $\gamma_{th}(G) + \kappa(G) = 3 = 2n - 3$.

Conversely, assume $\gamma_{th}(G) + \kappa(G) = 2n - 3$, for $n \geq 3$. Then the following cases are to be considered.

(i) $\gamma_{th}(G) = n$ and $\kappa(G) = n - 3$

(ii) $\gamma_{th}(G) = n - 1$ and $\kappa(G) = n - 2$

(iii) $\gamma_{th}(G) = n - 2$ and $\kappa(G) = n - 1$.

Case 1. $\gamma_{th}(G) = n$ and $\kappa(G) = n - 3$.

Since for any connected graph G , $\gamma_{th}(G) \leq n - 1$, this case is not possible.

Case 2. $\gamma_{th}(G) = n - 1$ and $\kappa(G) = n - 2$

$\gamma_{th}(G) = n - 1$ if and only if $G \cong P_3$ and $\kappa(P_3) = 1 = n - 2$. Therefore $G \cong P_3$.

Case 3. $\gamma_{th}(G) = n - 2$ and $\kappa(G) = n - 1$.

If $\kappa(G) = n - 1$, then $G \cong K_n$, $n \geq 3$. But $\gamma_{th}(G) = 0$ for $G \cong K_n$, $n \geq 3$.

Therefore, $G \cong P_3$.

Theorem 2.5.3: Let G be a connected graph. Then $\gamma_{th}(G) + \kappa(G) = 2n - 4$ ($n \geq 4$) if and only if $G \cong K_4 - e$, C_4 .

Proof:

Assume $\gamma_{th}(G) + \kappa(G) = 2n - 4$, $n \geq 4$. Then the following cases are to be considered.

(i) $\gamma_{th}(G) = n$ and $\kappa(G) = n - 4$

(ii) $\gamma_{th}(G) = n - 1$ and $\kappa(G) = n - 3$

(iii) $\gamma_{th}(G) = n - 2$ and $\kappa(G) = n - 2$

(iv) $\gamma_{th}(G) = n - 3$ and $\kappa(G) = n - 1$

There is no connected graph G with $\gamma_{th}(G) = n$, $\kappa(G) = n - 4$ and $\gamma_{th}(G) = n - 1$, $\kappa(G) = n - 3$.

Case 1. $\gamma_{th}(G) = n - 2 = \kappa(G)$

Since $\kappa(G) \leq \delta(G)$, $\delta(G) \geq n - 2$.

(a) If $\delta(G) > n - 2$, then $G \cong K_n$, $n \geq 3$. But $\gamma_{th}(G) = 0$, for $G \cong K_n$, $n \geq 4$.





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(b) Assume $\delta(G) = n - 2$. Then G is isomorphic to $K_n - Y$, where Y is a matching in K_n , $n \geq 3$ and $\gamma_{th}(G) \leq 2$. By observation 5.2.1, $\gamma_{th}(G) \geq 2$, for any connected graph G . Therefore, $\gamma_{th}(G) = 2$. $\gamma_{th}(G) = n - 2 \Rightarrow n = 4$. Therefore, $G \cong K_4 - e, C_4$.

Case 2. $\gamma_{th}(G) = n - 3$ and $\kappa(G) = n - 1$

If $\delta(G) = n - 1$, then $G \cong K_n$, $n \geq 3$. But $\gamma_{th}(K_n) = 0$, for $n \geq 4$.

Therefore, $G \cong K_4 - e, C_4$.

CONCLUSION

In this paper, we find the tree hop number and bounds for some graphs.

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<p style="text-align: center;">Figure 2.1</p>	<p style="text-align: center;">Figure 2.2</p>
<p>Figure 1: In the graph G given in Figure 2.1, minimum tree hop dominating set is $\{v_6, v_7, v_8\}$ and $\gamma_{th}(G) = 3$.</p>	<p>Figure 2: For the graphs given in Figure 2.2, tree hop dominating sets do not exist and $\gamma_{th}(G) = 0$.</p>
<p style="text-align: center;">Figure 2.3</p>	<p style="text-align: center;">Figure 2.4</p>
<p>Figure 3: In the graph G given in Figure 2.3, the set $\{v_6, v_7\}$ is both a minimum hop dominating set and a minimum tree hop dominating set. Therefore, $\gamma_h(G) = \gamma_{th}(G) = 2$.</p>	<p>Figure 4: In the graph G given in Figure 2.3, the set $\{v_6, v_7\}$ is both a minimum hop dominating set and a minimum tree hop dominating set. Therefore, $\gamma_h(G) = \gamma_{th}(G) = 2$.</p>



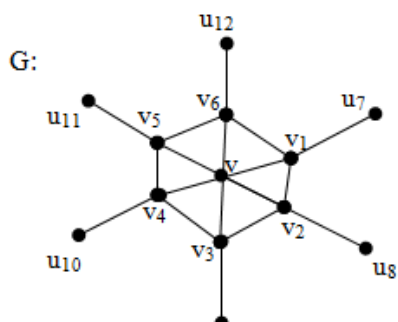


Figure 6: In the graph G given in Figure 2.5, minimum tree hop dominating set is $\{v_6, v_7, v_8\}$ and $\gamma_{th}(G) = 3$.

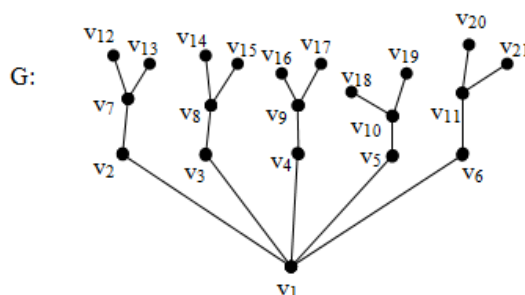


Figure 7: In the graph G given in Figure 2.6, minimum tree hop dominating set is $\{v_6, v_7, v_8\}$ and $\gamma_{th}(G) = 3$.

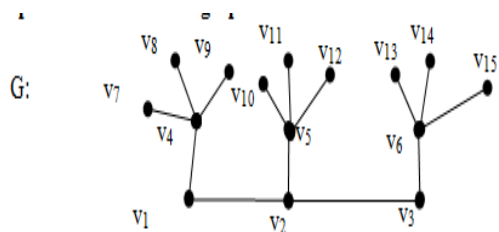


Figure 8: In the graph G given in Figure 2.7, minimum tree hop dominating set is $\{v_1, v_2, v_3\}$ and $\gamma_{th}(G) = 3$.

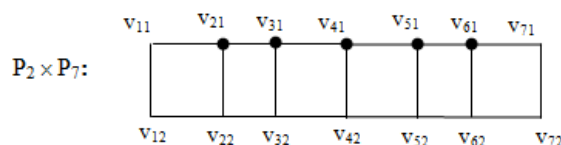


Figure 9: In the graph $P_2 \times P_7$ given in Figure 2.5, minimum tree hop dominating set is $\{v_{21}, v_{31}, v_{41}, v_{51}, v_{61}\}$ and $\gamma_{th}(P_2 \times P_7) = 5$.

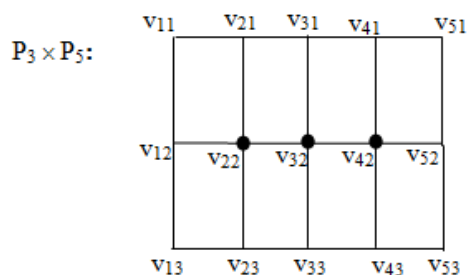


Figure 10: In the graph $P_3 \times P_5$ given in Figure 2.6, minimum tree hop dominating set is $\{v_{22}, v_{32}, v_{42}\}$ and $\gamma_{th}(P_3 \times P_5) = 3$.

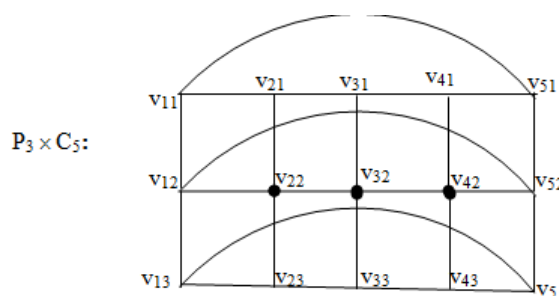


Figure 11: In the graph $P_3 \times C_5$ given in Figure 2.7, minimum tree hop dominating set is $\{v_{22}, v_{32}, v_{42}\}$ and $\gamma_{th}(P_3 \times C_5) = 3$.





The Hydrological Simulation of a River Basin using the SWAT-CUP Model

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ABSTRACT

The Pancheshwer basin, which spans an area of 13,659.50 km² and is located along the international boundary between India and Nepal, was studied for its water balance using a analysis for semi-distributed hydrological model and the Soil and Water Assessment Tool (SWAT) model. The basin was divided into six smaller basins for the sake of this study. Further, the SWAT model was used to construct the land cover, slope, and soil classifications. We examined monthly discharge data from 1982 to 1986 to calibrate the model. Based on the goodness-of-fit statistics derived from a parameter sensitivity analysis, calibration and validation were improved. Finally, we evaluated the Pancheshwer basin's seasonal and annual water balance over the same time frame. These calculations utilized Latin hypercube sampling at the 2.5 % and 97.5 % levels of the cumulative distribution for an output variable influenced by parameter uncertainty propagation. This 95 % prediction uncertainty (PPU) represents the model's output in a stochastic calibration framework. It should be noted that the model output is not a single result but rather an envelope of feasible solutions that are defined by the 95 PPU and obtained from particular parameter





ranges. The findings indicate that the Pancheshwer Basin is a suitable candidate for the application of the SWAT CUP methodology.

Keywords: Hydrological modeling; SWAT model; Metrological data, Validation Calibration

INTRODUCTION

Water in the hydrological cycle is contained in almost equal amounts overall in all its forms; nevertheless, global water availability per person is quickly declining as a result of rising living standards and population growth. Utilizing the water resources that are available as efficiently as possible is therefore necessary. India is currently dealing with a number of difficult problems in the water sector, despite having great strides in the development of its water resources field since gaining its independence. For the watershed's forecasts to be considered reasonable, the hydrologic process parameters must be regulated during the calibration phase. Activities like stream flow, sedimentation, and nutrient transport should be changed sequentially because of the links among components from shared transport processes. [6]. Manual calibration can be laborious in situations where the model has a large number of uncertainties and complex hydrologic models are developed. To address that issue, numerous automated or semi-automated calibrating techniques were created. In SWAT CUP model uncertainty analysis and semi-automatic calibration have been incorporated into SWAT2009 [7]. An interface designed specifically for SWAT is called SWAT-CUP. A semi-automated method (SUF2) that combines sensitivity and uncertainty analysis with both automated and manual calibration is included in the decision-making framework offered by SWAT-CUP. The model calibration and validation were conducted with help of SUFI-2 technique. In order to provide light on potential solutions for issues pertaining to water resources, models of water resources depict physical, environmental, economic, and social processes [20]. In order to forecast hydrological variables, scientists from all around the world have been creating empirical or conceptual hydrological models for the past forty years. Physically-based models include simulation models, which simulate processes to evaluate various scenarios, and optimization models, which specify objectives and modify parameters to achieve them. Many water resource models reduce assumptions and parameterization in order to get around the spatial features of a problem. The main purpose of the Soil and Water Assessment Tools (SWAT) model. Several studies have examined the SWAT model's performance in predicting runoff and sediment outputs at daily, monthly, and annual periods. In addition to providing goodness-of-fit data, parameter sensitivity analysis aids in the improvement of calibration and uncertainty evaluations. For uncertainty analysis and calibration, the SUFI-2 program was utilized. This study used sensitivity analysis of water balance components in the Pancheshwer basin, India, under local conditions, to validate, assess, and calibrate the SWAT CUP model. The observed monthly discharge data from 1982 to 1986 served as the basis for calibration. Numerous statistical measures, such as the coefficient of determination, Nash-Sutcliffe coefficient, Index of Agreement, modified forms of the Index of Agreement and Nash-Sutcliffe coefficient, percent bias, d, and R^2 were used to check the model's performance. Positive results from these assessments showed satisfactory calibration and validation. The SUFI-2 method was applied to the sensitivity analysis.

Study Area

This study focuses on the Pancheshwer basin, which is situated between Nepal and Uttarakhand, India. It spans latitudes 29° 07' 30" to 29° 48' North and longitudes 79° 55' to 80° 35' East. It includes the Indian districts of Pithoragarh, Bageshwar, Almora, and Champawat, as well as the districts of Baitadi and Dharchula in Nepal. Of the 12,100 km² total drainage area of the basin, about 9,720 km² are in India while the rest 2,380 km² are in Nepal. The basin precipitation annually approximately 2000 mm, with the monsoon season, which runs from June to September, accounting for over 75% of the entire amount of precipitation. An estimated 1,620 mm of precipitation falls on average each year. The winter season usually starts in October and lasts through February. March marks the start of summer, which lasts until the end of May. Pre-feasibility report, 2015: Of the entire population in the area, 49.5 percent is working, and 50.5 percent resides in the villages and is dependent on others. Clay loam (42.44 %), glacial





loam (8.81 %), loam (9.46 %), and silty loam (39.29 %) make up the majority of the research region's soil, which spans an area of 5796.59 km², 1203.43 km², 1292.38 km², and 5366.99 km², respectively.

METHODOLOGY

Comparing observed data with the model's projected values is the process of model calibration. To produce forecasts that are reasonable in light of measured data, this procedure entails adjusting the model's input parameters. The following are the steps involved in manual calibration: (1) start the simulation; (2) compare the values that were observed and those that were simulated; (3) determine whether the results are acceptable; (4) if the results are not satisfactory, modify the input parameters within reasonable bounds using professional judgment; and (5) repeat the process until the best results are obtained. A semi-automated technique that combines sensitivity and uncertainty analyses with both automatic and human calibration is included into the SWAT-CUP framework. SUFI-2 was employed in the process of validating and calibrating the model.

SUFI 2 Running Procedure in The SWAT-CUP Model

SWAT-CUP implements the SUFI-2 calibration process by using multiple system files (exe) for user convenience. In a stochastic calibration approach, these 95PPUs are the model outputs. It is important to remember that we are dealing with an envelope of good solutions generated by some parameter ranges, not a single signal representing the model output. SUFI-2 first uses Latin Hypercube Sampling (LHS) to minimize the amount of multi-dimensional distribution samples required. The model receives input for SUFI-2 and updates successively for each set of parameters listed in par val.txt. The input files par inf.txt, observed.txt, par val.txt, and var file name.txt are necessary for the best possible simulation. The SUFI-2 objective fn.exe calculates the ideal simulation number and settings. The uncertainty measures that best reflect the current iteration's best simulation results are included in the Summary stat.txt file. These metrics include p-factor, r-factor, R², Nash-Sutcliffe (NS), modified R² (bR²), mean squared error (MSE), and sum of squares of residuals (SSQR). The pre-feasibility assessment for the Pancheshwer Dam project 2015 provided the sets of hydrological and metrological data. Monthly discharge statistics were obtained for 1962–1992 years. The SWAT hydrological model was calibrated using daily discharge data from 1982 to 1985, and the discharge data from 1986 to 1992 were used to validate the model. For the long-term SWAT project, which ran from 1979 to 2014, Global Weather Data provided daily recordings of temperature, relative humidity, rainfall, wind speed, and other meteorological factors. We re-projected the DEM, soil, and land use datasets using the coordinate system WGS_1984_UTM_ZONE_44N. Advanced Spaceborne Thermal Emission and Reflection (ASTER) elevation measurements were used to evaluate the topography of the basin. The Global Land Cover Facility provided cloud-free digital LANDSAT (TM) data with a spatial resolution of 30 m x 30 m. In March 1990, during the fall season, satellite data was gathered to construct a land use/cover map of the Manchester basin.

Sub Basin and HRU Definition

The Pancheshwer basin was determined to have a mean elevation of 3971.5 meters, with minimum and maximum altitudes of 144 and 7799 meters, respectively. By carefully selecting outlet sites that included observed discharge data, the research region was divided into six sub-basins (Figure 3) to facilitate model calibration and validation. Each sub-basin border designates the end of a reach, or the point at which all upstream flow data is collected and fed into the downstream sub-basin and reach. Once flow lines have been constructed, the model determines HRUs using additional physical layers. The model defined these distinct hydrological response units. In its maiden run, the model produced 434 HRUs.

RESULTS AND DISCUSSION

Model calibration & parameters

Several parameters are provided by model calibration, which can be modified by the user. Either manually or automatically, the model output can be adjusted to closely resemble the observed data. The outlet stream flow was



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calibrated using SWAT-CUP. SWAT simulates water balance on a daily time series, and the calibration was conducted on monthly data using observed monthly runoff data from 1982 to 1986. The "model warm-up" phase was given the first three years (1979–1981) of the modeling era in order to realistically construct the initial conditions of internal hydrological components, such as groundwater storage and soil moisture content. For particular reaches, dispersed changes were made to SWAT's hydrology-affecting parameters. Depending on the parameter's nature, the parameters were changed either through replacement or by applying a relative modification. All parameter changes, however, were rigidly limited to the predetermined complete variable or parameters ranges during the calibration. Groundwater delay time, effective hydraulic conductivity of the principal stream alluvium, and other input variables were considered for lag coefficient and n value for the mainstream to calibrate the model. Table 1 offers a concise description of the data used for model calibration.

Simulation of discharge using calibrated SWAT model

Data on monthly stream flows that were observed were compared and the stream flow data simulated by the sub-basin outlets of the validated SWAT model. Figure 4 clearly shows observed discharge, although sometimes at different magnitudes. Overall, the monthly predictions during the simulation period were generally accurate. With the exception of months with very severe storms and hydrological circumstances [3]. Two things can be blamed for the discrepancy: (1) Throughout the early monsoon season, base flow was overestimated, and (2) a curve number (CN) assignment that is slightly lower. This can be explained by the fact that high-intensity rainfall typically takes place between August and September, when the soil is already saturated and produces a larger discharge. In the event that heavy rain falls quickly after a dry spell. The model's predicted discharge closely resembles the measured levels for rainfall events with uniform distribution. The sparser distribution of meteorological stations and data in those places, where more discharge is anticipated, may explain why the prediction of discharge in locations with higher altitudes is lower. Its importance becomes clear when climatic information is viewed as a hydrological model's key motivating factor [10]. The 1:1 line and the monthly observed and simulated discharge for the calibration period are shown in Figure 4. It is evident from the graph that the simulated values are uniformly distributed around the 1:1 line at lower measured discharge values. The simulated values, however, hardly ever surpass the 1:1 line for higher observed discharge values, suggesting that the algorithm has a propensity to underestimate higher discharge rates.

A Nash-Sutcliffe model efficiency rating of 0.76 indicates that it performed the best for both the observed and simulated discharge during calibration period. Furthermore, d1 and E have respective values of 0.94, 0.55, and 0.85. A score of 1 in this context denotes a perfect fit, whereas a value of 0 implies no association. Percent Bias (PBIAS) has an ideal value of 0, which denotes accurate model simulation. The PBIAS value in this instance was discovered to be 9.52, which is regarded as "very good." The RSR value, which measures model simulation performance, was found to be 0.494, indicating a "good" rating.

Sensitivity and uncertainty analysis

The sensitivity analysis assisted in determining which variables needed to be precisely assessed in order to provide precise forecasts of watershed yields. In SUFI-2, uncertainty is measured using the 95PPU (95th percentile uncertainty) band. The p-factor and the r-factor are two statistical indicators used to compare the 95PPU band and discharge data. The percentage of observed data that falls inside the 95PPU band, including errors, is represented by the p-factor. These data points fall within the simulation uncertainty of the model, indicating a satisfactory fit. A model simulation that perfectly captures uncertainty and aligns with the actual data would have a p-factor of 1 and an r-factor of 0. The r-factor was 0.59 and the p-factor was 0.73 according to SUFI-2.

Global sensitivity Analysis

SWAT-CUP supports both global and a time sensitivity analysis, as well as general sensitivity analysis. In Figure 3, showing values or relative changes against the goal function, dot plots are used to display the pattern of sampling points and parameter sensitivity. These dot plots specifically showcase the ten sensitive parameters. Dotty plots (Figure 6) were used to illustrate the sensitivity of the model parameters involved in calibrating the SWAT model. Sharp & distinct peaks observed in the plots indicate parameters with a higher likelihood, while diffuse peaks in the cumulative distributions signify less skilled parameters in discharge forecast for the Pancheshwar basin.





Model validation

A simulation's accuracy in reflecting observed data is evaluated during the validation process, taking into account the model's or simulation's intended uses. The calibrated tested data or model was using another set of measured data to determine its ability to anticipate effects of the different scenarios on the Pancheshwar basin's water balance. In the validation process, observed discharge data from the independent validation period, which ran from 1987 to 1992, were used. For large river basins, it is ideal to conduct a multi-site validation process based on pre-performed sensitivity analyses. This becomes particularly important when the model is intended for regional-scale applications or considering climate variability. For the validation period (1987-1992), Figure 4.5 graphically compares make out and simulate or reproduce monthly discharge data. The simulated peak values generally exhibit a close resemblance to the observed discharge peaks observed from August to September in the years 1989, 1990, 1991, and 1992. However, for lower discharge magnitudes, the model tends to underestimate the values during January to March 1986, November to February 1987, November to March 1988, and November to January 1989. Furthermore, Figure 5.6 depicts scatter grams comparing the simulated and observed discharges from 1987 to 1992. Table 4.7 contains summaries of actual and generated monthly discharge statistics for all years. The R^2 and ENS were estimated to be shows 0.89 and 0.88, respectively, during the model validation procedure from 1986 to 1992. According to these figures, there is a good degree of consistency between the simulated and data is wants to monthly discharges over the specified time frame. The Modified forms of the all values of d, E and d1 were all calculated and get to be 0.97, 0.71, and 0.91. The values of PBIAS were found to be 3.52, indicating a very good level of consistency in the data used for validation. Additionally, the RSR, which represents the RSR error to observed data's standard deviation ratio was calculated as 0.35, indicating a "very good rating" in terms of model performance. That statistical analysis in Table 4, model validation is rated as "very good." A sizable part of the observed values fell within the 95PPU boundaries, demonstrating that the SWAT model's related uncertainties were kept to acceptable levels. This calibrated model can therefore be used for studies of land use and land cover (LULC), planning and management of water resources, and determining how climate change affects stream flow in the research area, among other uses. Figure 5 shows the sensitivity of the model parameters for SWAT calibration using dot plots. When a parameter's peak is clear and abrupt, it is regarded as extremely likely; when it is broad and represented by cumulative distributions, it is considered insensitive and may have less predictive value for discharge in the Pancheshwar basin.

CONCLUSIONS

Soil depth, soil evaporation compensation factor, shallow aquifer water threshold depth (GWQ MN), accessible water capacity, and erratic rainfall patterns (CN) were the most sensitive characteristics of the Pancheshwar basin. The basin is more vulnerable to severe flooding result of these causes. Furthermore, during the monthly simulations, the model was calibrated to yield mean, standard deviation, and maximum values of 569.5, 533.11, and 1179, respectively. The simulated monthly discharge's calibrated values of 515.3, 550.95, and 1926 show satisfactory performance. These findings show that the Pancheshwar Basin's hydrology may be evaluated using the SWAT model. Sensitivity of parameters used in SWAT model calibration was shown using dot plots. A parameter can be regarded as having the highest likelihood when it has a clear, sharp peak. Similarly, a dispersed peak represented by cumulative distributions was employed to derive the insensitive parameters, which showed that the parameter had lower predictive power for discharge in the Pancheshwar basin. Further, the HRU water balance analysis makes it possible to locate specific places where management strategies to enhance water use could be proposed. The Pancheshwar Basin's mean value was 3971 meters, with the lowest and maximum altitudes being 144 and 7799 meters, respectively. By enhancing basin management, practices such as strip cropping and vegetative filter strips can effectively reduce runoff. The Pancheshwar basin, the research region, is somewhat underutilized regarding the development and usage of water resources, as this suggests.





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Table.1: Sensitive parameters with their Range and matched range of values

Sl. No.	Parameters	Fitted Value	Minimum Value	Maximum Value
1	CN	0.16	-0.2	2.0
2	EPCO	0.10	0.0	1
3	ESCO	0.13	0.0	1
4	Alpha bf	0.10	0.0	1
5	GW Delay	39.45	30	450
6	GWQMN	261.25	0.0	500
7	CH N ₂	0.09	0.0	0.1
8	SOL AWC	0.030	0.0	1
9	REVAPMN	71.25	0.0	500
10	GW REVAP	0.04	0.0	0.1

Table.2: A statistical study of calibrated monthly flow simulations and observations was conducted for the years 1982-1986.

Statistical parameters	Discharge from Jan-1982 to Dec-1986 (m ³ /sec)	
	Observed	Simulated
Mean	569.5	515.3
Standard deviation	533.11	550.95
Maximum	1979	1926
Count	60	60
Determination Coefficient	0.79	
Nash-Sutcliffe efficiency	0.76	
Index of agreement	0.94	
Nash-Sutcliffe coefficient in modified form	0.55	
Modified form of Index of agreement	0.85	
Percent bias	9.52	





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RMSE-observations Ratio of Standard Deviation	0.49
Erel	-0.45
Drel	0.64

Table.3: Presents the global sensitivity parameters for the Pancheshwar basin along with their respective rankings

Sensitivity Rank	Name of Parameter	T value	P value
1	CN ₂	-5.53	0.00
2	ALPHA	5.49	0.00
3	GW- DELAY	-5.07	0.00
4	GWQMN	1.40	0.16
5	ESCO	-0.70	0.48
6	EPCO	0.62	0.54
7	GW- REVAP	-0.99	0.33
8	REVAPMN	-0.26	0.79
9	SOL- AWC	0.58	0.56
10	CH- N ₂	0.37	0.71

Table.4: Comparison of the monthly discharge values from simulation and observation

Statistical parameters	Discharge from Jan-1986 to Dec-1992 (m ³ /sec)	
	Observed	Simulated
Mean	581.77	564.967
Standard deviation	569.13	627.476
Maximum	2145	2266
Count	72	72
R ²	0.89	
NSE	0.88	
d	0.97	
Modified NSE	0.72	
Modified d	0.91	
Percent bias	3.52	
RMSE-observations Standard deviation Ratio	0.35	
Erel	0.74	
Drel	0.94	



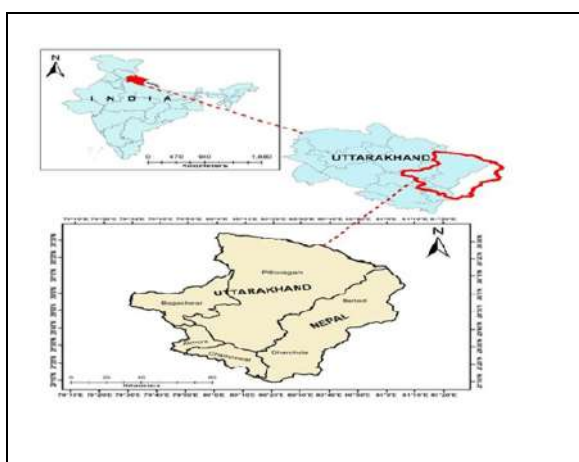


Figure.1: The location of the study area

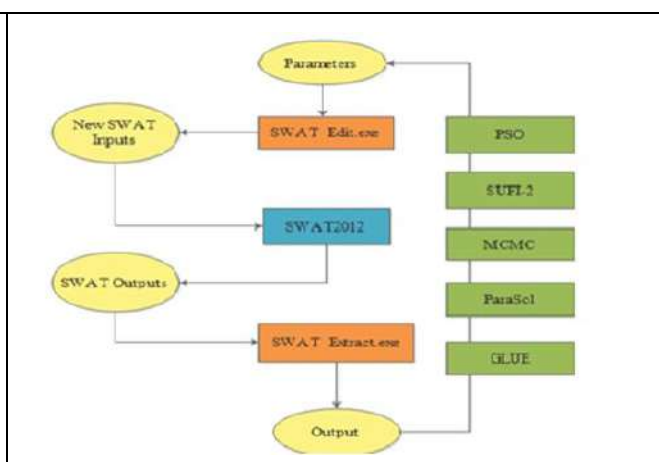


Figure.2: Overall programmed structure of SWAT-CUP

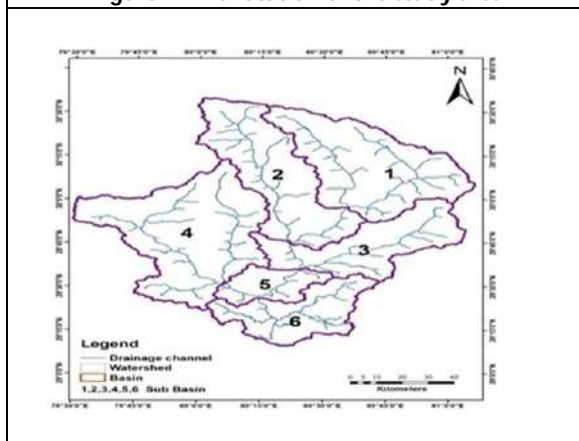


Figure.3: Delineated Sub-basin of the Pancheshwar basin

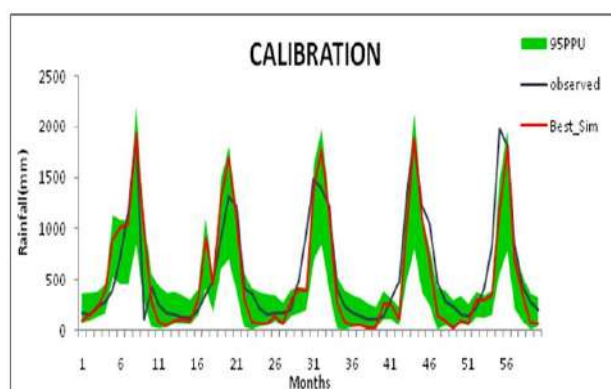


Figure.4: Observed and calibrated discharge during the period of 1982–1986

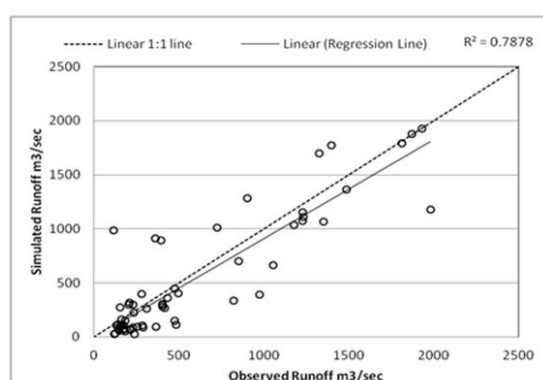


Figure.5: Model calibration, a comparison of observed and simulated discharges from 1982 to 1986 was made

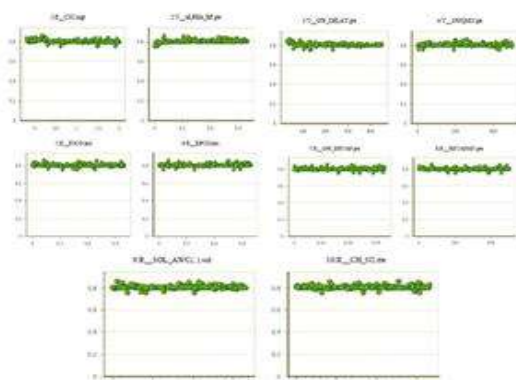


Figure.6: Dotty plots for sensitivity analysis of the basin



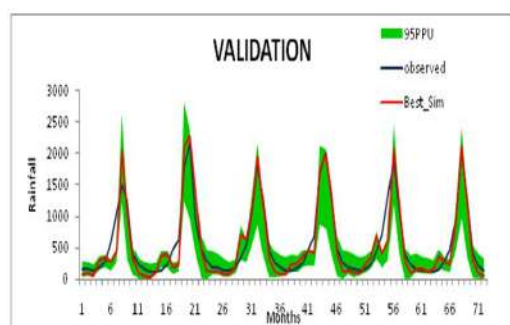


Figure.7:Model validations, observed and simulated discharge from 1987 to 1992 in the Pancheshwar basin

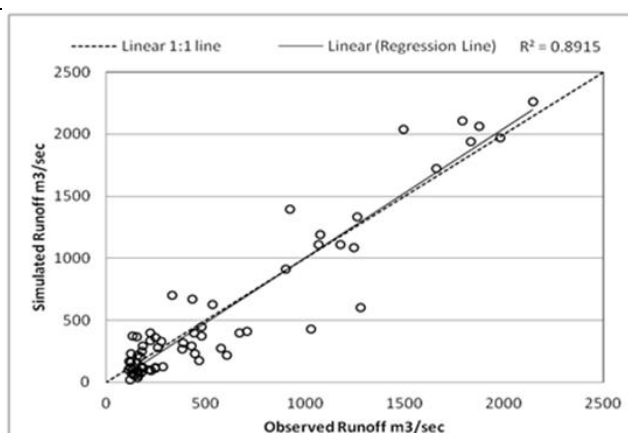


Figure.8:Comparison of real and predicted discharge from 1987 to 1992 in the Pancheshwar basin for model validation





Physiotherapy in Rotationplasty : Paving the Path to Mobility and Function

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ABSTRACT

A rare and progressive form of cerebrovascular disease, terminal segment of the intracranial carotid artery and its major branches exhibit increasing stenosis, which is the hallmark of moyamoya disease, a long-term cerebrovascular occlusive illness. The immune system, genetics, and other variables are associated with the incidence of Moyamoya illness. The etiology and pathology of Moyamoya disease remain largely unknown. Moyamoya disease is by abnormal collateral blood vessels in the carotid artery in the brain and its branches, which form the circle of willis, as well as bilateral occlusion caused by developmental abnormalities.¹ we will discuss some case studies in this study and physiotherapy in Moyamoya disease will be the main topic of this short communication.

Keywords: The immune system, genetics, and other variables are associated with the incidence of Moyamoya illness.

INTRODUCTION

The non-atherosclerotic abnormality of structure known as Moyamoya disease is characterized by progressive narrowing or blockage of the intracranial carotid arteries and their proximal branches.[2] Asia has a greater



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prevalence of Moya Moya disease than any other part of the world.[3] Incidence of moya moya disease is slightly higher in males than females.[2]The cause of this disease is still unknown.[4] Seizures, headaches, cognitive dysfunction, ischemic stroke, hemorrhagic stroke, and transient ischemic attack are some signs and symptoms of this disease.[5]Moya moya disease patients may experience a range of prognosis, including gradual, fulminant episodes, sporadic attacks, or abrupt neurological loss.[6] Hemodynamic alterations are brought on by recurrent ischemia of the brain and intracranial bleeding. Many vascular chemicals and cells, as well as molecules are associated with angiogenesis and vasculogenesis have been studied in the hunt for the pathophysiology of moya moya disease, according to clinical investigations, the damaged arteries do not exhibit inflammatory or arteriosclerotic variations that could obstruct them. Instead, a combination of lumen thrombosis and smooth muscle cell hyperplasia leads to vascular blockage.[7]

Aim of the study

The aim of this study is to discuss some studies and summarize the role of physiotherapy in Moya Moya Disease. At the age of 33, a patient was diagnosed with Moya Moya disease. The patient was assessed utilizing the Berg balance scale and One Min-Step test. To enhance motor function, physiotherapy intervention was carried out in accordance with the impairments. For eight weeks, the patient received an intense physical therapy regimen that comprised of functional and strengthening exercises, 5 days/week, 60-90 minutes. During the assessment, shoulder pain and disability index was used which highlighted the disabilities of arm, shoulder and hand. Shoulder instability was seen, along with a decreased range of motion and muscular power. The movement with mobilizing mulligan concept was applied three times a week to increase range of motion. Peripheral mechanics were directly impacted by movement and mobilization, which decreased the nociceptive mechanoreceptor activity and increased tactile and mechanoreceptor activation. Increased descending inhibition, the decoupling of pain and movements, and a decreased fear of movement are some of the indirect effects on central processes. With Moya Moya disease, physical therapy rehabilitation may enhance functional status and reduce impairment. After the eight-week regimen, there was a remarkable improvement in shoulder discomfort and shoulder muscular strength. The patient's was able to carry out activities of daily living pain-free.[4] The other case is of a 3.3 year old boy wherein a pediatric neurologist diagnosed the patient with Moya Moya syndrome, the child had not been able to hold his head upright for the last two years. It was reported that the youngster met all of the milestones and was apparently normal up until the age of eight and a half months. An upward stare and clenching of teeth accompanied the first convulsion, which lasted for three seconds. At nine and a half months and eleven months of age, respectively, there was a history of two further epileptic episodes. One plantar reflex was active in both cases. We saw that the infant had heightened reflexes in the upper as well as the lower body. Additionally, it was shown that there was an increase in tone in the lower and upper limb muscles. Three to four days a week, an entire period of 45 to 60 minutes were allotted for the therapy.

The intervention included visual stimulation, oral motor facilitation for three to five minutes, and neck holding, rolling, creeping, and weight bearing on hands for seven to ten minutes each. In addition to all of these workouts, walking on a treadmill was done for ten minutes.[8] Moyamoya illness may be a rare, progressive type of cerebrovascular disorder that starts as an obliterative vascular disease and develops to a compensating proliferating vasculopathy. It's caused by arteries becoming blocked inside the basal ganglia, which are located at the base of the brain. In 1969, Suzuki and Takaku first used the term Moyamoya (MM) to refer to the development of tiny collaterals that originate in the thalamus that travel through the basal ganglia as a result of progressive stenosis. Moyamoya disease is an artery disorder that can result in stroke in young patients. This is a long-term illness marked by prominent arterial collateral circulation, bilateral stenosis, and occlusion of the capillaries surrounding the Willis circle. The first record of it was found in Japan. Traditional angiographic results for stenosis is arterial collateral circulation that is prominent and the occlusion of the arteries that surround the circle of will's. The first record of its discovery was in Japan. The diagnosis of Willis's vessel occlusion or stenosis is made using traditional angiographic findings. In this article, I talk about a 9-year-old boy who was identified as weak at 6 months old. Three weeks before this admission, he experienced unrelenting slurred speech, drooping of the right side of his face, and head trauma from a tree fall. A computed tomography scan of the head and an electroencephalogram were utilized to evaluate



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him. After the child's recovery, he was released from the hospital after four days. Continued medication, physical therapy led to a gradual improvement in the child's condition.[9]

CONCLUSION

This study concluded that physiotherapy intervention has a vital role in Moya Moya Disease most commonly to enhance motor functions and improve patient's quality of life, rehabilitative physical therapy may improve functional status and lessen disability. Ultimately, according to above case studies there was a noticeable improvement in shoulder soreness and shoulder muscle strength. The patient's capacity to perform daily activities without assistance was improved for their recovery from Moya Moya disease.

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Efficacy of Organic Fertilizer and Biostimulant on Growth and Yield of Beetroot (*Beta vulgaris* L.) Cv. 'Detroit Dark Red' Grown in Lower Hills of Uttarakhand

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ABSTRACT

A field experiment was planned and conducted during 2022-23 at Horticulture Research Block, School of Agriculture Sciences, SGRRU, Dehradun, Uttarakhand. To investigate the "Efficacy of organic fertilizers and Biostimulant on growth and yield of Beet root (*Beta vulgaris* L.) cv. "Detroit Dark Red" grown in lower hills of Uttarakhand. The experiment was laid out in randomized block design with three replications and ten treatments. The treatments comprised following levels of different organic fertilizers with different concentrations viz. T₁ (Control), T₂ (Farm Yard manure @22t/ha), T₃ (Vermicompost @ 5t/ha), T₄ (Jeevamrutha @100%), T₅ (Biostimulant @3%), T₆ (FYM @22t/ha + Vermicompost @5t/ha), T₇ (Vermicompost @5t/ha + Jeevamrutha @100%), T₈ (FYM @22t/ha + Biostimulant @3%), T₉ (FYM @11 t/ha + Vermicompost @2.5 t/ha + Jeevamrutha @50% + Biostimulant @1.5%) and T₁₀ (FYM @22t/ha + Vermicompost @5t/ha + Jeevamrutha @100% + Biostimulant @3%). The sowing of crop variety Detroit Dark Red, was done on November 18, 2022. Observations and studies on various growth and yield characters were recorded using standard methods of measurements. Of all the organic treatments, T₁₀ of soil application with (FYM @22 t/ha + Vermicompost @5 t/ha + Jeevamrutha @100% + Biostimulant 3%) has shown the significant improvement in plant height (38.21cm), number of leaves per plant (38.21), diameter of root (7.60cm) and root yield (7.41kg/plot) than other treatments. The treatment T₉ recorded

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maximum weight of root (120.07g) and root: shoot ratio (0.48). The treatment T₈, recorded maximum fresh weight of leaf (43.50g). However, treatment T₇ recorded maximum leaf length (24.46cm) and root yield (25.10 t/ha) at final harvest.

Keywords: Organic fertilizers, randomized, vermicompost, biostimulant, Jeevamrutha.

INTRODUCTION

Beetroot (*Beta vulgaris* L.) belongs to the family Chenopodiaceae, now reclassified as Amaranthaceae (Chadha, 2020), and possesses a chromosome count of $2n=18$. It is commonly called as beet, swiss chard, spinach beet, sea beet, garden beet, white beet, sugar beet, fodder beet and chukandar (in hindi). It is essentially a cool season root vegetable crop eaten all over the world. Like many modern vegetables, beetroot was first cultivated by the Roman. By the nineteenth century it held great commercial value when it was discovered that beets could be converted into sugar. (Dwivedi *et.al*; 2017). It's one of the world's ancient vegetables (Bangare *et.al*; 2022). Beta name come from Romans. It was not cultivated until 3rd century and not developed until 9th century by German and French breeders. According to 2021-2022 Statistical data, the total area under vegetables in India is 11.37 MHa with the production of 209.14 MT (NHB, 2023). In India, Maharashtra produces the maximum amounts of beetroots followed by Tamil Nadu, Karnataka, Punjab, Haryana, Uttar Pradesh, Arunachal Pradesh, Himachal Pradesh and West Bengal is increasing its production of beetroot gradually and many farmers are shifting from potatoes to beetroot due to increase in price and output. Beet root has higher concentration of biologically active ingredients like betalain, inorganic nitrates, carotenoids, polyphenols and folates as well as minerals and fiber also found in beets in good amounts. It also contains Vitamins (B₁, B₂, B₃, B₆ and B₁₂). All parts of this plant have different medicinal uses, such as anti-oxidant, anti- depressant and anti- microbial, anti- fungal and anti-inflammatory properties (Ceduet *et.al*; 2020). Beetroots are also rich in Vitamin C, A, E and K. Beetroot is a good tonic food for health, it has been known for its amazing, health benefits for almost every part of the body. The interest in red beetroot effects on human health has exploded during the past few decades. The roots and greens are great for women health and for those planning pregnancies. As it is rich source of folic acid essential for pregnant women to reduce risk of Spina bifida. Beetroot is one of the original superfoods and gaining popularity as a "New superfood", owing to recent studies that its juice improves the athletic performances, lowers blood pressure and increase blood flow. It has anti-inflammatory and anti- oxidant effects which scavenge free radical from the cells promoting cancer prevention by inhibiting the tumor cells proliferation, reducing the risk of cardiovascular diseases, and expelling kidney stones (Babarykin *et.al*; 2019).

Beetroot also helps in skin disorders, lowers cholesterol, gastric ulcers, constipation and anemia where high content of iron in beets regenerates and reactivates the red blood cells and supplies fresh oxygen to the body. Dried beetroots can be consumed directly in form of chips as a substitute to traditional snacks (Ingle *et.al*; 2017). Beetroot can be eaten raw, boiled steamed and roasted. It is grown for food uses like pickling, canning, salad, juice, jam etc. Beet powder is used as a coloring agent for many food products. Some frozen pizzas use beet powder for coloring in tomato sauce (Chauchan *et.al*; 2020). In Australia and New Zealand, it's a common practice to include beetroot pickle as a topping on burgers. Additionally, red beet is utilized in the production of rich red, Burgundy-style wines. Its versatility extends beyond culinary applications; beetroot serves as a natural colorant in the textile industry and is also valued as a source of medicinal herbs. Organic fertilizers refer to materials used as occurring process. The decline in soil quality is becoming a significant process of soil degradation. The optimizing organic fertilizer incorporation practices in crop land is essential to enhancing crop productivity and soil health (Zhou *et.al*; 2022). Organic fertilizers improve the soil structure, provide a wide range of plant nutrients, and add beneficial microorganism to the soil. Farmyard manure is explained as a perfect source of nutrients for plant growth as well as for soil microbiota. It is one of the efficient and effective organic manures. Vermicompost is described as "bio-oxidation and stabilization of organic material involving the joint action of earthworms and mesophilic micro-organisms. Earthworm and vermicompost can boost horticultural production without agrochemicals. Additionally,



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organic manures (viz. compost, vermicompost, poultry manure and farmyard manure) have the capacity to mobilize crop nutrients and improve crop productivity. Furthermore, the addition of dung, jaggery, urine, gramme flour and milk as constituents in organic inputs, which are rich in carbon and nitrogen may be the reason for the higher total microbial counts in the fermented liquid organic nutrient formulations (FLONFs), which include panchgavya, matkakhanda, jeevamrutha and beejamrit. Jeevamrutha includes two words “Jeeva” and “Amrutham” which is derived from Sanskrit and are the most used by Hindus. The word “Jeeva” means a living organism and the word “Amrutham” stands for an elixir of life which has the capability to extend the life of any living organism. (Sailaja *et al.*; 2019). Biostimulant i.e. “Plant biostimulants are substances and materials, with the exception of nutrients and pesticides, which, when applied to plant, seeds or growing substrates in specific formulations, have capacity to modify physiological process of plants in a way that provides potential benefits to growth, development and or stress responses” (Rouphael *et al.*; 2020). The decision to conduct the present experiment with organic fertilizers such as Jeevamrutha and biostimulants for beetroot cultivation in the low hills of Uttarakhand is driven by the scarcity of research in this area. Recognizing the lack of studies on the efficacy of these specific fertilizers on beetroot crops in your region, this experiment seeks to address this gap in knowledge. By investigating the impact of Jeevamrutha and biostimulants on beetroot cultivation in the unique environmental conditions of Uttarakhand's low hills, you aim to provide valuable insights that can benefit local farmers and contribute to sustainable agricultural practices in the region.

MATERIALS AND METHOD

The present research work was carried out at Horticulture Research Block, Department of Horticulture, School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand during the rabi season of 2022–23. The experiment was laid out in Randomized Block Design (RBD) and replicated thrice. Total ten treatments were tried namely T₁ (control), T₂ (Farm Yard manure @22t/ha), T₃ (Vermicompost @ 5t/ha), T₄ (Jeevamrutha @100%), T₅ (Biostimulant @3%), T₆ (FYM @22t/ha + Vermicompost @5t/ha), T₇ (Vermicompost @5t/ha + Jeevamrutha @100%), T₈ (FYM @22t/ha + Biostimulant @3%), T₉ (FYM @11 t/ha + Vermicompost @2.5 t/ha + Jeevamrutha @50% + Biostimulant @1.5%) and T₁₀ (FYM @22t/ha + Vermicompost @5t/ha +Jeevamrutha @100% + Biostimulant @3%). The soil of the research field was sandy loam in texture having pH of 7.12 with available nitrogen (220.04%), available phosphorus (9.1 kg ha⁻¹) and available potassium (18.1 kg ha). The Beetroot cultivar “Detroit Dark Red” was chosen for research purpose. Organic fertilizers i.e., Vermicompost, FYM, Jeevamrutha as well as Biostimulant were incorporated in experimental field as per the treatments at the time of final field preparation. The seed were sown on 18/11/2022. All the cultural practices were done at regular intervals as per the requirement of crop during the course of research work. During the experimentation, from each replication, randomly selected five plants were used for recording various observations on growth and yield characters during whole of the cropping period at 60, 90, 120 days after sowing and at final harvest. The obtained data were statistically analyzed with using standard statistical method as suggested by Gomez and Gomez (1996).

RESULT AND DISCUSSION

The various growth and yield characters were significantly influenced by different doses of organic fertilizers as compared to control during the course of investigation. The data presented in Table-1, 2 and 3 were showed that the significant improvement was noticed when applied different combinations of organic fertilizers as compared to control. The findings of the present investigation were recorded and are thoroughly discussed below:

Plant height (cm)

The observation data of plants height recorded at 60 DAS, 90 DAS, 120 DAS and at Final harvest was presented in Table 2 and Fig.1 revealed significant differences among the treatments. At 60 DAS, the maximum plant height (14.82 cm) was recorded in T₁₀ (FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%) and the minimum plant height (8.43cm) was recorded in T₁ (control@100% soil). Whereas, plant height in T₂ (10.27cm), T₃



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(10.22cm) and T₄ (10.33cm) were at par with each other. The Plant height in T₅ (12.56cm) and T₇ (12.55cm) was also at par with each other. However significant difference was observed in treatment T₈ (FYM @ 22t/ha + BS@ 3%) for Plant height i.e., (13.54cm). At 90 DAS, the maximum plant height (27.28cm) was recorded in T₁₀ (FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant@ 3%) and the minimum plant height (16.17cm) was recorded in T₁ (control@100% soil). The significant difference was observed in plant height of T₂ (20.21cm) FYM @ 22t/ha, T₃ (19.27cm) VC @ 5t/ha and T₄ (18.17cm) JV @ 100%. At 120 DAS the maximum plant height (35.15cm) was recorded in T₁₀ with FYM @ 22t/ha + VC @ 5t/ha + JV @ 100% + BS@ 3% and minimum (25.55cm) was recorded in T₁ (control @100% soil). The significant difference was recorded with treatment T₆ (33.06 cm) FYM @ 22t/ha + VC @5t/ha, T₈ (31.12cm) FYM @ 22t/ha + BS@ 3% and T₉ (32.10cm) FYM @ 11t/ha + VC@ 2.5t/ha + JV @50% + BS@ 1.5%. The treatment T₃ (30.22cm) and T₄ (30.21cm) were at par with each other for plant height. At final harvest the maximum plant height was recorded in T₁₀ (38.2 cm) with FYM @ 22t/ha +VC @ 5t/ha + JV @ 100% + BS@ 3% and the minimum plant height (19.60cm) was recorded in T₁ (control @100% soil). However, the treatment T₆ (34.20) and T₉ (34.16) were at par with each other. This variation might be due to nitrogen being a major element has a profound effect on plant growth and development, and as a constituent of proteins and also its effect on production of plant hormones in plants. The findings are in agreement with (Jagadeesh *et.al*; 2018) in beet root.

Number of leaves per plant

The observation of number of leaves per plant, recorded at 60 DAS, 90 DAS, 120 DAS and at Final harvest was presented in Table 2 and Fig.2 revealed significant differences among the treatments. At 60 DAS, number of leaves per plant ranged from (2.23) to (3.13). The maximum number of leaves (3.13) was recorded in treatment T₅ with Biostimulant @ 3% and the minimum number of leaves per plant (2.23) was recorded in T₁ (control @100% soil). Whereas, the result of the treatment T₂ (2.33) and T₄ (2.33) shows the similar number of leaves per plant which was at par with treatment T₆ (2.30). At 90 DAS, the maximum number of leaves (6.40) was recorded in T₅ with Biostimulant @ 3% and the minimum number of leaves per plant (5.17) was recorded in T₁ (control @100%). Whereas, the result of the treatment T₇ (5.50) and T₉ (5.50) shows the similar Number of leaves per plant. At 120 DAS, the maximum number of leaves (10.40) was recorded in T₅ with Biostimulant @ 3% and T₁₀ (10.40) FYM @ 22t/ha + VC @ 5t/ha + JV @ 100% + BS@ 3%. The minimum number of leaves per plant (8.83) was recorded in T₁ (control @100% soil). However, significant difference was observed in treatment T₂ (FYM @ 22t/ha) for number of leaves per plant i.e., (6.60). This variation might be due to combined effect of all fertilizers. As the organic fertilizers contains high amount of nutrients which helps for proper growth and development of vegetative structures i.e. leaves. The more photosynthates production is directly correlated to higher leaves number per plant and availability of nutrients and sunshine. The results are in line with the findings of (Jagadeesh *et.al*; 2018) and (Hussain and Kerketta, 2023) in beet root.

Leaf length (cm)

The observation of leaf length (cm) recorded at 90 DAS, 120 DAS and at Final harvest was presented in Table 2 and Fig.3 revealed significant differences among the treatments. At 90 DAS, maximum leaf length (12.25cm) was recorded in treatment T₇ with VC @ 5t/ha + JV @ 100% and the minimum leaf length (7.34cm) was recorded with T₁ (control @100% soil). Whereas, leaf length in T₄ (10.25cm) and T₈ (10.23cm) were at par with each other. At 120 DAS, the maximum leaf length (18.33cm) was recorded in treatments T₇ with VC @ 5t/ha + JV @ 100% and the minimum leaf length (11.16cm) was recorded in T₁ (control @100% soil). At final harvest the maximum leaf length (25.46cm) was recorded in treatment T₇ with VC @ 5t/ha + JV @ 100% and the minimum leaf length (21.58cm) was recorded with T₁ (control @ 100% soil). However, significant difference was observed in treatment T₅ (Biostimulant @ 3%) for leaf length i.e., (22.95cm). This may be due to Vermicompost possessing plant growth hormones (e.g., indole acetic acid, gibberellins and cytokinin's) and other plant growth regulators which promote increased microbial activities by earthworms which significantly increased the growth of plants. The observations are also in agreement with the findings of (Maloisane and Kayombo, 2022) in beet root.

Leaf width (cm)

The observation of leaf width recorded at 90 DAS, 120 DAS and at Final harvest was presented in Table 2 and Fig.4 revealed significant differences among the treatments. At 90 DAS, the maximum leaf width (6.43cm) was recorded in



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T₅ with Biostimulant @ 3% and the minimum leaf width (3.39cm) was recorded in T₁ (control@ 100% soil). Whereas, leaf width in T₇ (5.39cm) and T₈ (5.35cm) were at par with each other. At 120 DAS, the maximum leaf width (13.51cm) was recorded in T₅ with Biostimulant @ 3% and the minimum leaf width (8.58cm) was recorded in T₁ (control@ 100% soil). However, significant difference was observed in treatment T₄ (JV@ 100%) for leaf width i.e., (9.26cm). At final harvest, the maximum leaf width (18.23cm) was recorded in T₅ with Biostimulant @ 3% and the minimum leaf width (13.10cm) was recorded in T₁ (control @ 100% soil). This may be due to an explanation for such activities by plant Biostimulants are the fact that they are made of up mixtures of low molecular weight forms of organic N (amino acids and oligopeptides) which are precursors for the biosynthesis of plant hormones that stimulate plant growth and development. The findings are also in agreement with the findings of (Jolayem *et al.*; 2021) in sugar beet.

Fresh weight of leaf (g)

The observation of fresh weight of leaf recorded at 90 DAS, 120 DAS and at Final harvest was presented in Table 3 and Fig.5 revealed significant differences among the treatments. At 90 DAS, the maximum fresh weight of leaf (1.55g) was recorded in T₇ with Vermicompost @ 5t/ha + Jeevamrutha @ 100% and the minimum fresh weight of leaf (0.22g) was recorded in T₃ Vermicompost @5t/ha. However, T₅ (1.21g) and T₈ (1.21g) shows similar fresh weight of leaf which was at par with treatment T₉ (1.22g). Whereas, significant difference was observed in treatment T₁ (0.73g) and T₃ (0.22g) for fresh weight of leaf. At 120 DAS, the maximum fresh weight of leaf (1.42g) was recorded in T₈ with FYM @ 22t/ha + Biostimulant @ 3% and the minimum fresh weight of leaf (0.70g) was recorded in T₂ with FYM @ 22t/ha. However, T₄ (1.34g), T₉ (1.33g) and T₁₀ (1.30g) were at par with each other. Whereas, significant difference was observed in treatment T₂ (0.70g) and T₆ (0.88g) for fresh weight of leaf. At final harvest the maximum fresh weight of leaf (43.50g) was recorded in T₈ with FYM @ 22t/ha + Biostimulant @ 3% and the minimum fresh weight of leaf (29.72g) was recorded in T₁ (control @100% soil). However, T₅ (42.94g), T₆ (40.77g), T₈ (43.50g) T₉ (43.45g) and T₁₀ (42.92g) were at par with each other. Whereas, significant difference was observed in T₁ (control @ 100%soil) for fresh weight of leaf i.e., (29.72g). This may be due to, the lower amount of water inside the leaves and decreased cell expansion resulting in dense biomass production of leaves and as plant weight directly contributes to yield per plant. The findings are in similar with the results of (Jahan *et al.*; 2019) in carrot.

Dry weight of leaf (g)

The observation of dry weight of leaf recorded at Final harvest was presented in Table 3 and Fig.6 revealed significant differences among the treatments. At Final harvest, dry weight of leaf ranged from 0.30g to 1.27g. The maximum dry weight of leaf (1.27g) was recorded in treatment T₅ with Biostimulant @ 3% and the minimum dry weight of leaf (0.30g) was recorded in treatment T₁₀ with FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%. However, dry weight of leaf in treatment T₂ (0.76g) and T₇ (0.77g) were at par with each other. Whereas, significant difference was observed in treatment T₅ (1.27g) and T₉ (1.22g) for the dry weight of leaf. This might be due to the excellence of high level of organic fertilizers which produce better growth for beet root plants and shows higher dry weight of plant, The findings are in similar with the results of (Jahan *et al.*; 2019) in carrot.

Total Fresh weight of plant (g)

The observation of total fresh weight of plant (g), recorded at Final harvest was presented in Table 3 and Fig.7 revealed significant differences among the treatments. At Final harvest, total fresh weight ranged from 317.30g to 167.14g. The maximum total fresh weight of plant (317.30g) was recorded in treatment T₆ with FYM@ 22t/ha + Vermicompost @ 5t/ha and the minimum total fresh weight of plant (167.14g) was recorded in treatment T₁ with control @ 100%. However, total fresh weight of plant in treatment T₂ (247.99g), T₃ (235.02g) and T₈ (246.34g) were at par with each other. Whereas, significant difference was observed in treatment T₁ (167.14g) and T₄ (158.94g) for the total fresh weight of plant. This might be due to weight of plant directly depends on higher photosynthates produced that is stored in roots too. The findings are in similar with the results of (Hussain and Kerketta,2023) in beetroot.



Shivani Saklani *et al.*,**Total dry weight of plant (g)**

The observation of total dry weight of plant (g), recorded at Final harvest was presented in Table 3 and Fig.8 revealed significant differences among the treatments. At Final harvest, total dry weight ranged from 3.39g to 2.15g. The maximum total dry weight of plant (3.39g) was recorded in treatment T₇ with Vermicompost @ 5t/ha + Jeevamrutha @ 100% and the minimum total dry weight of plant (2.15g) was recorded in treatment T₁ with control @ 100%. However, treatment T₅ (2.26g) T₉ (2.26g) shows the similar dry weight of plant which was par with treatment T₃ (2.21g) and T₈ (2.25g). whereas, significant difference was observed in treatment T₁ (2.15g) for the total dry weight of plant. This might be due to since plants have a high composition of water and the level of water in a plant will depend on the amount of water in its environment weight of plant directly depends on higher photosynthates produced that is stored in roots too. The findings are in similar with the results of (Hussain and Kerketta, 2023) in beetroot.

Length of root (cm)

The observation of length of root (cm), recorded at Final harvest was presented in Table 3 and Fig.9 revealed significant differences among the treatments. At Final harvest length of root ranged from 9.26cm to 12.63cm. The maximum length of root (12.63cm) was recorded in treatment T₄ with Jeevamrutha @ 100% and the minimum length of root (9.26cm) was recorded in treatment T₁ with control @ 100%. However, treatment T₂ (10.46cm) T₃ (10.10cm) T₅ (10.85cm) was at par with each other. Whereas, the significant difference was observed in treatment T₁ (9.26cm) for the length of root. This might be due to higher content of phosphorous, nitrogen, calcium and micronutrients content in Jeevamrutha the nutrients solubilized in the soil, the subsequent accumulation of those nutrients have made them available to plants throughout their growth cycle, resulting in an increase in root characters due to Jeevamrutha application. The findings are in similar with the results of (Vibha *et.al*; 2022)

Diameter of root (cm)

The observation of diameter of root (cm), recorded at Final harvest was presented in Table 3 and Fig.10 revealed significant differences among the treatments. At Final harvest Diameter of root ranged from 7.60cm to 5.20cm. The maximum diameter of root (7.60cm) was recorded in treatment T₁₀ with FYM@ 22t/ha + Vermicompost 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3% and the minimum diameter of root (5.20cm) was recorded in treatment T₁ with control @ 100%. However, T₇ (7.14cm) T₈ (7.50cm) T₉ (7.16cm) and T₁₀ (7.60cm) was at par with each other. Whereas, significant difference was observed in treatment T₁ (5.20cm) and T₃ (5.36cm) for the diameter of root. The maximum diameter of root (7.60cm) was recorded in T₁₀ with FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%. The minimum diameter of root was recorded in control T₁ (5.20cm). This may be due to the decrease in bulk density and increase in porosity and water holding capacity of the soil due to organic fertilizers sources might have contributed in increasing root diameter of the plants. The highest root diameter recorded may be attributed to enhanced cell division and quick cell multiplication. The enhancement in root diameter in beet root plant with application of vermicompost supply organic matter and beneficial microorganisms, improving soil structure and nutrient availability. The findings are similar with (Tiwari and Prasad, 2022) in beetroot.

Weight of root (g)

The observation of weight of root (g), recorded at Final harvest was presented in Table 3 and Fig.11 revealed significant differences among the treatments. At Final harvest weight of root ranged from 53.45g to 115.90g. The maximum weight of root (115.90g) was recorded in treatment T₁₀ with FYM@ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3% and the minimum weight of root (53.45g) was recorded in treatment T₁ with control @ 100%. However, treatment T₄ (80.82g) and T₈ (86.84g) at par with each other. This might be due to as organic fertilizers play a direct role in plant growth as a source of all necessary macro and micro-nutrients in available forms during mineralization, improving physical and physiological properties of soil. The similar findings have been reported by Kushwah (2020) in sugar beet.



**Root: Shoot ratio**

The observation of root:shoot ratio recorded at Final harvest was presented in Table 3 and Fig.11 revealed significant differences among the treatments. At Final harvest root: shoot ratio ranged from 0.24 to 0.48. The maximum root: shoot ratio (0.48cm) was recorded in treatment T₉ with FYM @ 11t/ha + Vermicompost 2.5t/ha + Jeevamrutha @50% + Biostimulant @1.5% and the minimum root: shoot ratio (0.24) was recorded in treatment T₂ with FYM@22t/ha and T₅ (0.24) BioStimulant @3%. However, of root:shoot ratio in treatment T₂ (0.24) and T₅ (0.24) was found similar along with T₄ (0.35cm) and T₈ (0.35) at par with each other. This might be due to that the root: shoot ratio provides insights on where the sugar beet allocates the most carbon in the current phase of its growth. The similar findings have been reported by (Hadiret.al; 2020) in sugar beet.

Root yield (kg/plot)

The observation root yield (kg/plot), recorded at Final harvest was presented in Table 3 and Fig.12 revealed significant differences among the treatments. At Final harvest, root yield (ranged from 2.67 to 7.41 kg/plot. The maximum root yield (7.41kg/plot) was recorded in treatment T₁₀ with FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%. and the minimum root yield (2.67kg/plot) was recorded in treatment T₁ with control @ 100%. whereas, significant difference was observed in treatment T₄ (4.01kg/plot) for the root yield. This might be due to as it depends directly or even indirectly on earliness of plant along with plant height and number of leaves per plant too. It was seen in experimentation yield had direct positive correlation. These results are in close conformity with the findings of (Hussain and Kerketta, 2023) in beetroot.

Root yield (t/ha)

The observation root yield (t/ha), recorded at Final harvest was presented in Table 3 and Fig.13 revealed significant differences among the treatments. At Final harvest, root yield (t/ha) ranged from 8.91 to 25.10t/ha. The maximum root yield (25.10t/ha) was recorded in treatment T₇ with Vermicompost 5t/ha + Jeevamrutha @100% and the minimum root yield (8.91t/ha) was recorded in treatment T₁ with control @ 100%. However, the significant difference (8.91t/ha) and (9.92t/ha) was observed in treatment T₁ and T₂ for the root yield (t/ha). This might be due to higher root yield per plot and as it also depends directly or even indirectly on earliness of plant along with plant height and number of leaves per plant too. It was seen in experimentation yield had direct positive correlation. These findings are in close conformity with the results of Kushwah (2020) in beetroot.

CONCLUSION

On the basis of present investigation on “Efficacy of organic fertilizers and Biostimulant on growth and yield of Beet root (*Beta vulgaris* L.) cv. “Detroit Dark Red” grown in lower hills of Uttarakhand” it can be concluded that the treatment T₁₀ (FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%) was recorded maximum plant height (cm), number of leaves per plant, diameter of root (cm) and root yield (kg/plot) in beetroot. Whereas, in the treatment T₉ maximum weight of root (g) and root:shoot ratio was recorded. However, maximum leaf length (cm) and root yield (t/ha) was recorded in the treatment T₇. Whereas, the treatment T₈, recorded maximum fresh weight of leaf (43.50g). The treatment T₆ recorded maximum Total fresh weight of plant (317.30g) and Total dry weight of plant (3.44g). The treatment T₅ recorded maximum leaf width (18.23cm) and dry weight of leaf (1.27g). The treatment T₄ recorded maximum length of root (12.63cm). The present investigation, shows that supplementation of FYM, Vermicompost along with Jeevamrutha and Biostimulant improved soil fertility status which resulted in higher yield performance. Therefore, it could be recommended under present agro-climatic conditions in order to obtain sustainably higher yield and quality of beetroot.





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Table.1:Treatment details

No. of Treatment	Combinations	Concentration
T ₁	Control	Soil @100%
T ₂	FYM	@22t/ha
T ₃	Vermicompost	@5t/ha
T ₄	Jeevamrutham	@100%
T ₅	Biostimulant	@3%
T ₆	FYM + Vermicompost	@22t/ha + @5t/ha
T ₇	Vermicompost + Jeevamrutha	@5t/ha + @100%
T ₈	FYM + Biostimulant	@22t/ha + @3%
T ₉	FYM + Vermicompost + Jeevamrutha + Biostimulant	@11t/ha + @2.5t/ha + @50% + @1.5%
T ₁₀	FYM + Vermicompost + Jeevamrutha + Biostimulant	@22t/ha + @5t/ha + @100% + @3%

Table.2: Effect of organic fertilizers on plant height(cm), number of leaves per plant, leaf length (cm) and leaf width(cm) of beetroot at different harvest intervals.

Treatment	Plant height (cm)				Number of leaves per plant				Leaf length (cm)			Leaf width (cm)		
	60 DAS	90 DAS	120 DAS	At Final harvest	60 DAS	90 DAS	120 DAS	At Final harvest	90 DAS	120 DAS	At Final Harvest	90 DAS	120 DAS	At Final Harvest
T ₁	8.43	16.17	25.55	28.24	2.23	5.17	8.83	9.30	7.34	11.16	21.58	3.39	8.58	13.10
T ₂	10.27	20.21	29.20	30.10	2.33	5.40	6.60	10.40	9.20	14.10	24.36	4.44	10.15	15.06





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T ₃	10.2 2	19.2 7	30.2 2	35.13	2.6 0	5.1 0	10.2 0	10.09	9.33	14.2 0	24.50	3.5 5	10.2 8	14.24
T ₄	10.3 3	18.1 7	30.2 1	32.16	2.3 3	5.5 5	8.30	9.90	10.2 5	13.0 7	23.33	3.6 0	9.26	16.08
T ₅	12.5 6	23.2 1	28.1 0	30.26	3.1 3	6.4 0	10.4 0	11.53	9.98	16.1 7	22.95	6.4 3	13.5 1	18.23
T ₆	12.2 1	24.1 4	33.0 6	34.20	2.3 0	5.2 3	8.40	9.96	10.5 4	15.2 6	24.43	4.5 3	11.2 1	16.25
T ₇	12.5 5	22.2 9	25.2 1	29.20	2.4 3	5.5 0	9.97	10.30	12.2 5	18.3 3	25.46	5.3 9	10.3 3	17.23
T ₈	13.5 4	21.2 6	31.1 2	33.19	2.7 3	5.4 6	9.67	11.36	10.2 3	15.2 4	23.42	5.3 5	12.1 3	16.30
T ₉	14.2 1	21.5 7	32.1 0	34.16	2.5 0	5.5 0	9.90	11.36	11.2 2	17.3 5	25.29	5.7 2	10.1 9	16.27
T ₁₀	14.8 2	27.2 8	35.1 5	38.21	2.9 3	6.0 6	10.4 0	11.93	11.5 6	15.3 0	24.82	6.3 6	12.1 5	17.48
C.D(0.05 %)	0.89	0.35	0.26	0.05	0.1 8	NS	0.59	0.75	0.55	0.09	0.40	0.2 8	0.08	0.29
SE(m) ±	0.30	0.12	0.09	0.02	0.0 6	0.2 6	0.20	0.25	0.19	0.03	0.13	0.1 0	0.03	0.10
SE(d) ±	0.42	0.16	0.12	0.03	0.0 9	0.3 7	0.28	0.35	0.27	0.04	0.18	0.1 4	0.04	0.14
C.V.	4.30	0.95	0.50	0.12	4.0 9	8.2 4	3.69	4.10	3.14	0.34	0.96	3.5 0	0.40	1.05

Table 3: Effect of organic fertilizers on Fresh weight of leaf (g), Dry weight of leaf (g), total fresh weight of plant (g), total dry weight of plant (g), Length of Root (cm), Diameter of Root (g), Weight of Root (g), Root: Shoot Ratio, Root yield (kg/plot) and Root yield (t/ha) of beetroot at different harvest intervals

Treatment	Fresh Weight of leaf (g)			Dry weight of leaf (g)	total fresh weight of plant (g)	Total dry weight of plant (g)	Length of Root (cm)	Diameter of Root (cm)	Weight of Root (g)	Root : Shoot Ratio	Root yield (kg/plot)	Root yield (t/ha)
	90 DAS	120 DAS	At Final harvest	At Final harvest	At Final harvest	At Final harvest	At Final harvest	At Final harvest	At Final harvest	At Final harvest	At Final harvest	At Final harvest
T ₁	0.73	1.25	29.72	0.40	167.14	2.15	9.26	5.20	53.45	0.33	2.67	8.91
T ₂	1.11	0.70	37.25	0.76	247.99	2.33	10.46	6.44	59.50	0.24	2.98	9.92
T ₃	0.22	1.15	36.61	0.62	235.02	2.21	10.10	5.36	67.04	0.29	3.35	11.16
T ₄	1.34	1.34	35.02	0.38	158.94	3.27	12.63	6.84	80.82	0.35	4.01	13.38
T ₅	1.21	1.18	42.94	1.27	299.74	2.26	10.85	6.74	73.62	0.24	3.68	12.28
T ₆	1.35	0.88	40.77	0.95	317.30	3.44	11.88	6.94	92.69	0.29	4.63	15.44
T ₇	1.55	1.16	38.40	0.77	227.79	3.39	12.48	7.14	104.13	0.46	6.54	25.10
T ₈	1.21	1.42	43.50	0.35	246.34	2.25	10.71	7.50	86.84	0.35	4.34	14.44
T ₉	1.22	1.33	43.45	1.22	253.90	2.26	11.52	7.16	120.07	0.48	6.00	20.01
T ₁₀	1.19	1.30	42.92	0.30	289.33	3.34	11.45	7.60	115.90	0.40	7.41	24.67



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C.D(0.05 %)	0.34	0.23	0.07	0.23	70.28	0.06	0.21	0.34	4.28	0.07	0.30	3.90
SE(m) ±	0.13	0.06	0.02	0.08	23.47	0.02	0.07	0.12	1.43	0.02	0.10	1.30
SE(d) ±	0.18	0.11	0.03	0.11	33.10	0.03	0.10	0.16	2.02	0.03	0.14	1.84
C.V.	19.50	11.45	0.11	19.18	16.64	1.38	1.07	2.97	2.90	12.04	3.78	14.54

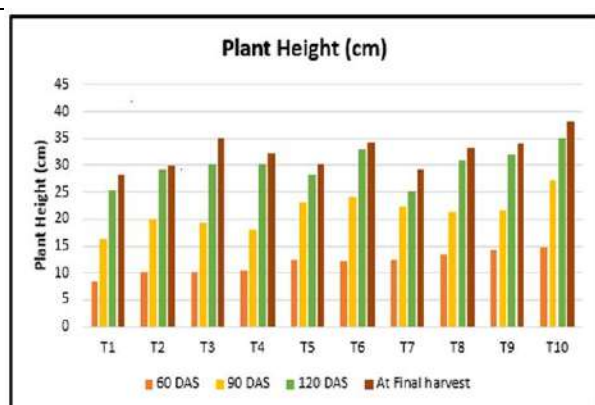


Figure.1: Plant height (cm) at different harvest intervals as influenced by application of organic fertilizer

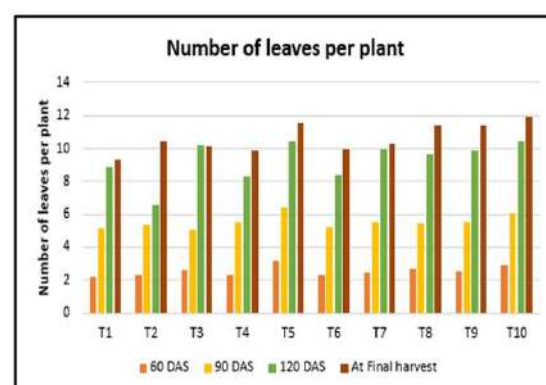


Figure.2: Number of leaves per plant at different harvest intervals as influenced by application of organic fertilizer

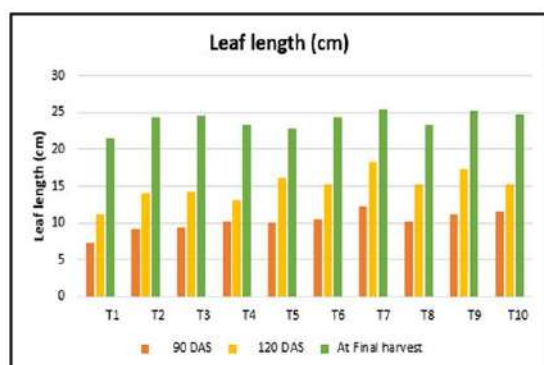


Figure.3: leaf length (cm) at different harvest intervals as influenced by application of organic fertilizer

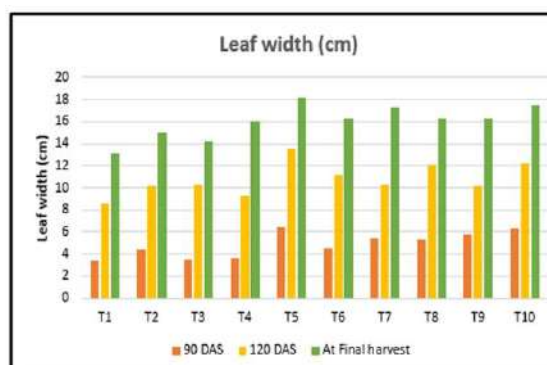


Figure.4: leaf width (cm) at different harvest intervals as influenced by application of organic fertilizer



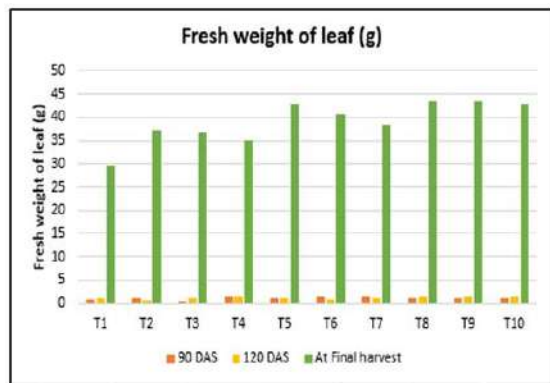
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Figure.5: Fresh weight of leaf (g) at different harvest intervals as influenced by application of organic fertilizer

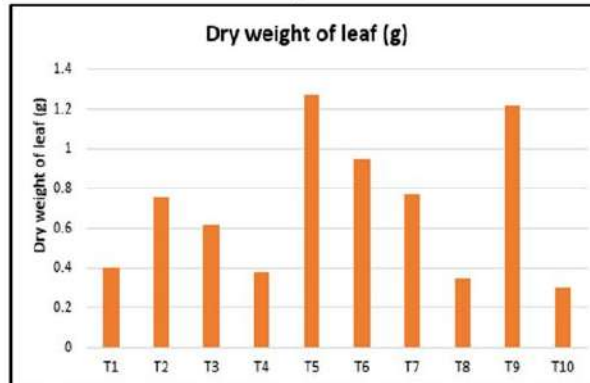


Figure.6: Dry weight of leaf (g) at final harvest intervals as influenced by application of various organic fertilizer

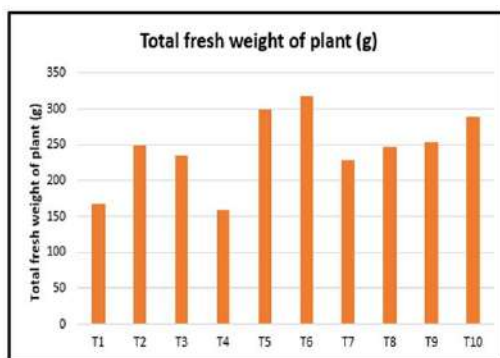


Figure.7: Total fresh weight of plant (g) at final harvest intervals as influenced by application of various organic fertilizer

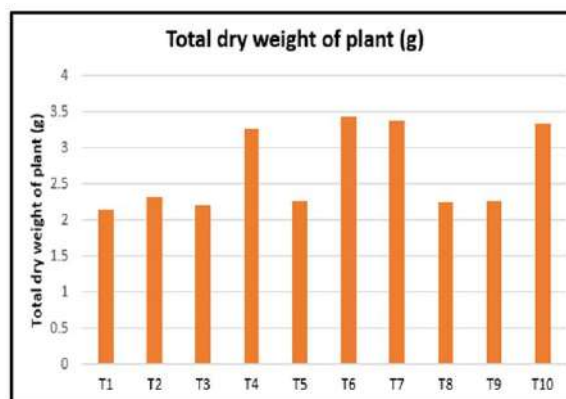


Figure.8: Total dry weight of plant (g) at final harvest intervals as influenced by application of various organic fertilizer

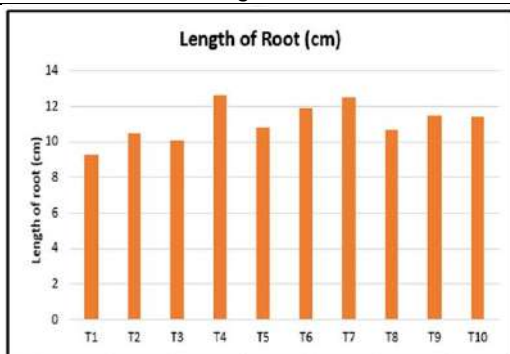


Figure.9: Length of root (cm) at final harvest intervals as influenced by application of various organic fertilizer

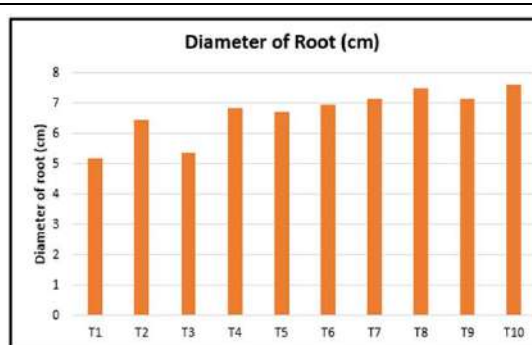


Figure.10: Diameter of root (cm) at final harvest intervals as influenced by application of various organic fertilizer



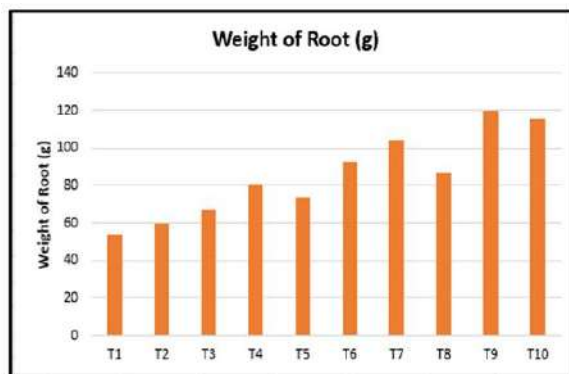


Figure.11: Weight of root (g) at final harvest intervals as influenced by application of various organic fertilizer

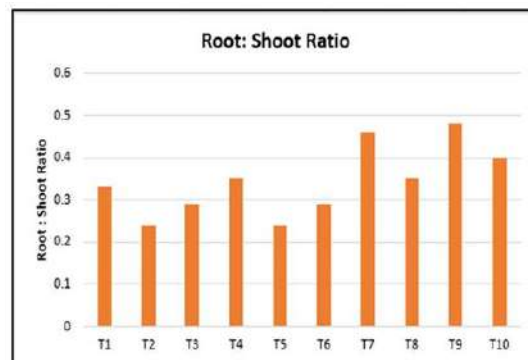


Figure.12: Root: Shoot Ratio at final harvest intervals as influenced by application of various organic fertilizer

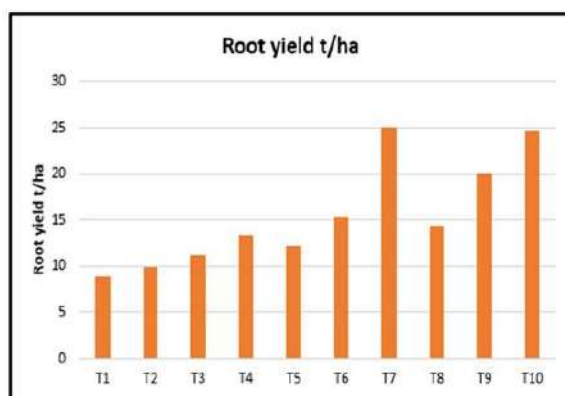


Figure.13: Root yield (t/ha) at final harvest intervals as influenced by application of various organic fertilizer





Analysis of a Liver Disorder using Three Newly Developed MCDM Models Integrated with Bipolar Nonagonal Fuzzy PSI Approach

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ABSTRACT

A novel Integrated c with $B_p N_n F$ -CoCoSo, $B_p N_n F$ -MOORA and $B_p N_n F$ -WASPAS method is presented in this study for medical diagnosis. Its objective is to improve the decision-making procedures in medical diagnosis by managing the unpredictability and complexity linked to medical symptoms and diagnoses. The fuzzy value in the system is defuzzified into crisp values utilizing the $CB_p N_n FCS$ (Converting bipolar nonagonal fuzzy data into crisp score) approach. Next, calculate the weight using the $B_p N_n F$ -PSI method, incorporating $B_p N_n F$ -CoCoSo, $B_p N_n F$ -MOORA and $B_p N_n F$ -WASPAS technologies. Utilising $B_p N_n F$ -MCDM methods and analysing symptom data from five patients with liver problems, determine the patient at a critical stage of the disease by examining the relationship between alternatives and criteria.

Keywords: MCDM, $B_p N_n F$ -PSI, $B_p N_n F$ -CoCoSo, $B_p N_n F$ -MOORA, $B_p N_n F$ -WASPAS

INTRODUCTION

Multi-Criteria Decision Making (MCDM) is a set of methods and processes used to evaluate and rank alternatives based on multiple, often conflicting criteria. It plays a crucial role in decision-making across various fields, such as engineering, healthcare, economics, and management. The primary aim of Multiple Criteria Decision Making (MCDM) is to aid decision-makers in choosing the optimal choice by methodically examining several criteria and



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their associated compromises. Multi-Criteria Decision Making (MCDM) is an essential field within decision theory that specifically deals with the assessment and selection of options that possess several, often contradictory evaluation criteria. Achieving an ideal result in real-world decision-making settings requires the careful balancing of several elements. Multi-Criteria Decision-Making (MCDM) is an essential procedure in the field of decision sciences, which entails the assessment and prioritization of various competing options according to several criteria. Conventional Multiple Criteria Decision Making (MCDM) methods frequently encounter difficulties associated with uncertainty and imprecision in existing data. In order to address the challenge of vagueness and ambiguity, Fuzzy Multiple Criteria Decision Making (MCDM) methods, such as Fuzzy Combined Compromise Solution (Fuzzy CoCoSo) and Fuzzy Multi-Objective Optimization by Ratio Analysis (Fuzzy MOORA), include fuzzy logic. The fuzzy Preference Selection Index (PSI) method is a multi-criteria decision-making technique that ranks alternatives by calculating a preference index based on the normalized performance of each criterion. It assigns weights to criteria and aggregates the values to determine the most preferred alternative, making it suitable for complex decision problems. The Fuzzy CoCoSo method is a recently developed technique that integrates the advantages of many compromise-based methods, enabling decision-makers to efficiently aggregate and rank alternatives. This approach utilizes fuzzy logic to address the issue of imprecision in criteria weights and performance ratings, therefore offering a decision-making framework that is more adaptable and realistic. Fuzzy CoCoSo improves the decision-making process by including fuzzy sets to better handle subjective and imprecise information commonly seen in complex situations. Fuzzy MOORA is an implementation of the conventional MOORA approach that integrates fuzzy logic to effectively handle uncertainty in the process of decision-making. This approach assesses several options by analysis of their performance ratios across several parameters, enabling a transparent comparison of the alternatives. Finite MOORA enhances the ranking procedure by using fuzzy sets, hence increasing its suitability for real-world scenarios characterized by ambiguous or incomplete data. Both the Fuzzy CoCoSo and Fuzzy MOORA algorithms offer robust frameworks for decision-making in uncertain scenarios, yielding more accurate and reliable outcomes in several practical domains such as engineering and healthcare.

Fuzzy Weighted Aggregated Sum Product Assessment (WASPAS) is a hybrid Multi-Criteria Decision-Making (MCDM) method that integrates fuzzy logic into the traditional WASPAS approach. By combining the Weighted Sum Model (WSM) and the Weighted Product Model (WPM) within a fuzzy framework, Fuzzy WASPAS allows decision-makers to handle uncertainty and imprecision in evaluating alternatives. In this method, performance values and criteria weights are expressed as fuzzy numbers, typically using linguistic terms like "low" or "high." The fuzzy decision matrix is normalized, and the final ranking of alternatives is obtained by calculating a combined score from the WSM and WPM components, with a parameter (λ) controlling the balance between the two. Fuzzy WASPAS is particularly useful in complex decision scenarios where exact data is not available, and subjective judgments need to be incorporated, making it applicable in fields such as healthcare, engineering, and environmental management. [1]Zadeh, L. (1965) Presented the fundamental notion of fuzzy sets, which established the basis for later fuzzy logic and decision-making models, impacting diverse applications in uncertainty modeling and decision support systems. [2]Opricovic, S., & Tzeng, G. H. (2003) Discussed defuzzification in a multi-criteria decision model, contributing to the operationalization of fuzzy numbers in decision-making, particularly in converting fuzzy inputs into crisp outputs. [3]Zhang, W. R., & Zhang, L. (2004) Developed YinYang bipolar fuzzy logic, providing a new dimension to traditional fuzzy logic by incorporating bipolarity, which is essential for complex decision-making scenarios involving positive and negative aspects. [4]Saraswat, S., & Digalwar, A. K. (2021) Applied a fuzzy multi-criteria decision-making approach combined with Shannon's entropy to evaluate energy alternatives, demonstrating the method's effectiveness in addressing sustainability issues in the energy sector. [5]Afrasiabi, A., Tavana, M., & Di Caprio, D. (2022) A comprehensive hybrid fuzzy MCDM model was introduced to facilitate sustainable and resilient supplier selection. This model demonstrates the utilization of fuzzy logic in supply chain management, specifically emphasizing sustainability and resilience. [6]Ezhilarasan, N., & Felix, A. (2023) Introduction of a bipolar trapezoidal fuzzy ARAS approach for the detection of TB comorbidities, demonstrating the incorporation of fuzzy logic in healthcare for the diagnosis of complicated diseases. [7]Akram, M., Shumaiza, N., & Alcántud, J. C. R. (2023) Explored MCDM methods with bipolar fuzzy sets, expanding the utility of bipolar fuzzy sets in decision-making processes by addressing both positive and negative criteria simultaneously. [8]Farooq, A., Nabeel, M., & Ali, G. (2023) Proposed





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novel applications of MCDM utilising cubic bipolar fuzzy models, emphasising their significance in medical and technical domains, namely for managing increased levels of uncertainty and complexity.[9]Chakraborty, S., et al. (2023) Conducted a comprehensive review of MCDM methods in healthcare, providing insights into the diverse applications of MCDM techniques, including fuzzy logic, in optimizing healthcare decisions. [10]Kursunoglu, N. (2024) Proposed a fuzzy MCDM framework for controlling methane explosions in coal mines, emphasizing the role of fuzzy logic in enhancing safety measures in high-risk environments. [11]Sampathkumar, S., et al. (2024) Utilising centroid and graded mean ranking techniques to analyse intuitionistic trapezoidal dense fuzzy sets in MCDM situations, particularly for robot selection, thereby enhancing the progress of fuzzy MCDM in the field of robotics. [12]Yu, J., et al. (2024) Utilized Fermatean fuzzy sets and the CoCoSo method for risk assessment in LNG storage tanks, demonstrating the effectiveness of fuzzy logic in risk management for industrial safety. [13]Natarajan, E., et al. (2024) Formulated a bipolar intuitionistic fuzzy decision-making model to choose efficient tuberculosis (TB) diagnosis techniques, demonstrating the capabilities of bipolar fuzzy logic in healthcare diagnostics.[14]Rasoanaivo, R. G., et al. (2024)

Introduced the CoCoFISo method, a new MCDM approach based on CoCoSo, providing an innovative solution for decision-making that integrates compromise and ideal solution concepts. [15]Jana, C., et al. (2024) Applied a hybrid MCDM method with a bipolar fuzzy approach to economic condition analysis, illustrating the applicability of bipolar fuzzy logic in economic decision-making. [16]Natarajan, E., & Augustin, F. (2024) Design and implemented a bipolar fuzzy decision-making system to evaluate the presence of high-risk coexisting TB in pregnant women. This system demonstrates the effectiveness of fuzzy logic in handling intricate healthcare situations. [17]Rong, Y., et al. (2024) Presenting a novel integrated group decision-making framework that incorporates MULTIMOORA-WASPAS with q-rung orthopair fuzzy information, this study contributes to the progress of fuzzy logic in collaborative decision-making settings. [18]Özlü, E. (2024)This study presents a new method for managing hesitation and bipolarity in decision-making processes by developing bipolar-valued complex hesitant fuzzy Dombi aggregating operators for MCDM issues. [19]Ali, G., et al. (2024) Extended the ELECTRE method for MCDM with spherical cubic fuzzy sets, demonstrating the method's capability to handle complex decision-making scenarios with multi-dimensional uncertainty.[20]Zhao, Z., et al. (2024)Presenting a decision support system that utilizes bipolar complicated fuzzy Hamy mean operators, this study demonstrates the incorporation of sophisticated fuzzy logic into decision support systems designed for intricate decision-making contexts. In this paper extended vision of Bipolar nonagonal fuzzy set in MCDM methods.This section 2 gives preliminaries definition for this paper. In Section 3, explain the proposed method $CB_p N_n FCS$ algorithm, proposed $B_p N_n F-PSI$, $B_p N_n F-CoCoSo$, $B_p N_n F-MOORA$ and $B_p N_n F-WASPAS$. In section 4, proposed integrating $B_p N_n F-PSI$ with $B_p N_n F-CoCoSo$, $B_p N_n F-MOORA$, $B_p N_n F-WASPAS$ method to solve medical diagnosis with numerical example in liver disorder.

2.Preliminaries

Definition 2.1. Definition of a fuzzy subset \mathcal{B} of the universal set $Z = \{z, \mu_{\mathcal{B}}(z) \mid z \in Z\}$, where $\mu_{\mathcal{B}}(z)$ is the membership function is a linear mapping $\mu_{\mathcal{B}}(z) : Z \rightarrow [0, 1]$.

Definition 2.2. A bipolar fuzzy set \mathcal{B}_p is a mathematical set defined by $\mathcal{B}_p = \{(z, \mu_{\mathcal{B}}^+(z), \mu_{\mathcal{B}}^-(z)) \mid z \in Z\}$, where $\mu_{\mathcal{B}}^+(z) : Z \rightarrow [0, 1]$ and $\mu_{\mathcal{B}}^-(z) : Z \rightarrow [-1, 0]$ Denote the positive and negative Membership Functions, correspondingly.

Definition 2.3. A \mathcal{B}_p is a bipolar fuzzy number defined on the real line \mathbb{R} , where its positive and negative Membership Functions must meet the following criteria:

- (i) \mathcal{B}_p is normal $\mu_{\mathcal{B}}^+(z) = 1, \mu_{\mathcal{B}}^-(z) = -1$.
- (ii) $\mu_{\mathcal{B}}^+(z), \mu_{\mathcal{B}}^-(z)$ are piecewise continuous.
- (iii) \mathcal{B}_p is convex $\mu_{\mathcal{B}}^+(\rho z_1 + (1 - \rho)z_2) \geq \min(\mu_{\mathcal{B}}^+(z_1), \mu_{\mathcal{B}}^+(z_2))$, for all $z_1, z_2 \in Z, \rho \in [0, 1]$.
- (iv) \mathcal{B}_p is concave $\mu_{\mathcal{B}}^-(\rho z_1 + (1 - \rho)z_2) \leq \max(\mu_{\mathcal{B}}^-(z_1), \mu_{\mathcal{B}}^-(z_2))$, for all $z_1, z_2 \in Z, \rho \in [-1, 0]$.



**Definition 2.4: Bipolar Nonagonal fuzzy number ($B_P N_n FN$)**

The $B_P N_n FN$ is defined as $\tilde{A}_{B_P N_n FN} = ((s_1^+, s_2^+, s_3^+, s_4^+, s_5^+, s_6^+, s_7^+, s_8^+, s_9^+)$

$(s_1^-, s_2^-, s_3^-, s_4^-, s_5^-, s_6^-, s_7^-, s_8^-, s_9^-))$ on the real line R then, the positive and negative membership of $B_P N_n FN$ are defined as

$$\mu_{\tilde{A}}^+(x) = \begin{cases} \zeta_1^+ \left(\frac{x-s_1^+}{s_2^+-s_1^+} \right) \text{ for } s_1^+ < x < s_2^+ \\ \zeta_1^+ + (\zeta_2^+ - \zeta_1^+) \left(\frac{x-s_2^+}{s_3^+-s_2^+} \right) \text{ for } s_2^+ < x < s_3^+ \\ \zeta_2^+ + (\zeta_3^+ - \zeta_2^+) \left(\frac{x-s_3^+}{s_4^+-s_3^+} \right) \text{ for } s_3^+ < x < s_4^+ \\ \zeta_3^+ + (1 - \zeta_3^+) \left(\frac{x-s_4^+}{s_5^+-s_4^+} \right) \text{ for } s_4^+ < x < s_5^+ \\ 1 \text{ for } x = s_5^+ \\ \zeta_3^+ + (1 - \zeta_3^+) \left(\frac{s_6^+-x}{s_6^+-s_5^+} \right) \text{ for } s_5^+ < x < s_6^+ \\ \zeta_2^+ + (\zeta_3^+ - \zeta_2^+) \left(\frac{s_7^+-x}{s_7^+-s_6^+} \right) \text{ for } s_6^+ < x < s_7^+ \\ \zeta_1^+ + (\zeta_2^+ - \zeta_1^+) \left(\frac{s_8^+-x}{s_8^+-s_7^+} \right) \text{ for } s_7^+ < x < s_8^+ \\ \zeta_1^+ \left(\frac{s_9^+-x}{s_9^+-s_8^+} \right) \text{ for } s_8^+ < x < s_9^+ \end{cases}$$

$$\mu_{\tilde{A}}^-(x) = \begin{cases} \zeta_1^- \left(\frac{x-s_1^-}{s_2^--s_1^-} \right) \text{ for } s_1^- < x < s_2^- \\ \zeta_1^- + (\zeta_2^- - \zeta_1^-) \left(\frac{x-s_2^-}{s_3^--s_2^-} \right) \text{ for } s_2^- < x < s_3^- \\ \zeta_2^- + (\zeta_3^- - \zeta_2^-) \left(\frac{x-s_3^-}{s_4^--s_3^-} \right) \text{ for } s_3^- < x < s_4^- \\ \zeta_3^- + (-1 - \zeta_3^-) \left(\frac{x-s_4^-}{s_5^--s_4^-} \right) \text{ for } s_4^- < x < s_5^- \\ -1 \text{ for } x = s_5^- \\ \zeta_3^- + (-1 - \zeta_3^-) \left(\frac{s_6^--x}{s_6^--s_5^-} \right) \text{ for } s_5^- < x < s_6^- \\ \zeta_2^- + (\zeta_3^- - \zeta_2^-) \left(\frac{s_7^--x}{s_7^--s_6^-} \right) \text{ for } s_6^- < x < s_7^- \\ \zeta_1^- + (\zeta_2^- - \zeta_1^-) \left(\frac{s_8^--x}{s_8^--s_7^-} \right) \text{ for } s_7^- < x < s_8^- \\ \zeta_1^- \left(\frac{s_9^--x}{s_9^--s_8^-} \right) \text{ for } s_8^- < x < s_9^- \end{cases}$$

Where $s_1^+ \leq s_2^+ \leq s_3^+ \leq s_4^+ \leq s_5^+ \leq s_6^+ \leq s_7^+ \leq s_8^+ \leq s_9^+$ and $s_1^- \leq s_2^- \leq s_3^- \leq s_4^- \leq s_5^- \leq s_6^- \leq s_7^- \leq s_8^- \leq s_9^-$.

Definition 2.5 Bipolar Nonagonal fuzzy arithmetic operation ($B_P N_n FN$):

Let $K = ((k_1^+, k_2^+, k_3^+, k_4^+, k_5^+, k_6^+, k_7^+, k_8^+, k_9^+), (k_1^-, k_2^-, k_3^-, k_4^-, k_5^-, k_6^-, k_7^-, k_8^-, k_9^-))$ and $V = ((v_1^+, v_2^+, v_3^+, v_4^+, v_5^+, v_6^+, v_7^+, v_8^+, v_9^+), (v_1^-, v_2^-, v_3^-, v_4^-, v_5^-, v_6^-, v_7^-, v_8^-, v_9^-))$ be two $B_P N_n FN$. Then, the arithmetic operation K and V are as follows,

$$\bullet (K+V) = \left(\begin{pmatrix} (k_1^+ + v_1^+), (k_2^+ + v_2^+), (k_3^+ + v_3^+), (k_4^+ + v_4^+), (k_5^+ + v_5^+), \\ (k_6^+ + v_6^+), (k_7^+ + v_7^+), (k_8^+ + v_8^+), (k_9^+ + v_9^+) \end{pmatrix}, \begin{pmatrix} (k_1^- + v_1^-), (k_2^- + v_2^-), (k_3^- + v_3^-), (k_4^- + v_4^-), (k_5^- + v_5^-), \\ (k_6^- + v_6^-), (k_7^- + v_7^-), (k_8^- + v_8^-), (k_9^- + v_9^-) \end{pmatrix} \right);$$

$$\bullet (K-V) = \left(\begin{pmatrix} (k_1^+ - v_1^+), (k_2^+ - v_2^+), (k_3^+ - v_3^+), (k_4^+ - v_4^+), (k_5^+ - v_5^+), \\ (k_6^+ - v_6^+), (k_7^+ - v_7^+), (k_8^+ - v_8^+), (k_9^+ - v_9^+) \end{pmatrix}, \begin{pmatrix} (k_1^- - v_1^-), (k_2^- - v_2^-), (k_3^- - v_3^-), (k_4^- - v_4^-), (k_5^- - v_5^-), \\ (k_6^- - v_6^-), (k_7^- - v_7^-), (k_8^- - v_8^-), (k_9^- - v_9^-) \end{pmatrix} \right);$$





$$\bullet (K^*V) = \left(\begin{array}{c} ((k_1^+ v_1^+), (k_2^+ v_2^+), (k_3^+ v_3^+), (k_4^+ v_4^+), (k_5^+ v_5^+), \\ (k_6^+ v_6^+), (k_7^+ v_7^+), (k_8^+ v_8^+), (k_9^+ v_9^+)) \\ ((k_1^- v_1^-), (k_2^- v_2^-), (k_3^- v_3^-), (k_4^- v_4^-), (k_5^- v_5^-), \\ (k_6^- v_6^-), (k_7^- v_7^-), (k_8^- v_8^-), (k_9^- v_9^-)) \end{array} \right)$$

$$\bullet (K/V) = \left(\begin{array}{c} ((k_1^+ / v_1^+), (k_2^+ / v_2^+), (k_3^+ / v_3^+), (k_4^+ / v_4^+), (k_5^+ / v_5^+), \\ (k_6^+ / v_6^+), (k_7^+ / v_7^+), (k_8^+ / v_8^+), (k_9^+ / v_9^+)) \\ ((k_1^- / v_1^-), (k_2^- / v_2^-), (k_3^- / v_3^-), (k_4^- / v_4^-), (k_5^- / v_5^-), \\ (k_6^- / v_6^-), (k_7^- / v_7^-), (k_8^- / v_8^-), (k_9^- / v_9^-)) \end{array} \right)$$

3. The Methodological approach

3.1. The proposed $CB_P N_n FCS$ algorithm

Defuzzification is the quantitative transformation of fuzzy or imprecise data into precise data. Fuzzy methods essentially include the transformation of a fuzzy number into a precise numerical value. The conventional methods for defuzzification include center of area, centre of sum, weighted average, and maximal techniques. The emerging technology is deficient in adequate bipolar fuzzy defuzzification methodology. The article[2] presents defuzzification methods for the Phase of Converting Fuzzy Data into Crisp Scores (CFCS). In this work, present the conversion of the technique into $CB_P N_n FCS$.

Step 1: Normalize each member of the $B_P N_n FN$.

$$\left(\begin{array}{c} k_{ij}^+ = \frac{k_{ij}^+ - \min(k_{ij}^+)}{\Delta_{min}^{max}}, l_{ij}^+ = \frac{l_{ij}^+ - \min(l_{ij}^+)}{\Delta_{min}^{max}}, m_{ij}^+ = \frac{m_{ij}^+ - \min(m_{ij}^+)}{\Delta_{min}^{max}}, \\ n_{ij}^+ = \frac{n_{ij}^+ - \min(n_{ij}^+)}{\Delta_{min}^{max}}, \\ o_{ij}^+ = \frac{o_{ij}^+ - \min(o_{ij}^+)}{\Delta_{min}^{max}}, p_{ij}^+ = \frac{p_{ij}^+ - \min(p_{ij}^+)}{\Delta_{min}^{max}}, q_{ij}^+ = \frac{q_{ij}^+ - \min(q_{ij}^+)}{\Delta_{min}^{max}}, \\ r_{ij}^+ = \frac{r_{ij}^+ - \min(r_{ij}^+)}{\Delta_{min}^{max}}, s_{ij}^+ = \frac{s_{ij}^+ - \min(s_{ij}^+)}{\Delta_{min}^{max}} \\ k_{ij}^- = \frac{k_{ij}^- - \min(k_{ij}^-)}{\Delta_{min}^{max}}, l_{ij}^- = \frac{l_{ij}^- - \min(l_{ij}^-)}{\Delta_{min}^{max}}, m_{ij}^- = \frac{m_{ij}^- - \min(m_{ij}^-)}{\Delta_{min}^{max}}, \\ n_{ij}^- = \frac{n_{ij}^- - \min(n_{ij}^-)}{\Delta_{min}^{max}}, \\ o_{ij}^- = \frac{o_{ij}^- - \min(o_{ij}^-)}{\Delta_{min}^{max}}, p_{ij}^- = \frac{p_{ij}^- - \min(p_{ij}^-)}{\Delta_{min}^{max}}, q_{ij}^- = \frac{q_{ij}^- - \min(q_{ij}^-)}{\Delta_{min}^{max}}, \\ r_{ij}^- = \frac{r_{ij}^- - \min(r_{ij}^-)}{\Delta_{min}^{max}}, s_{ij}^- = \frac{s_{ij}^- - \min(s_{ij}^-)}{\Delta_{min}^{max}} \end{array} \right)$$

Step 2: Calculate the left and right scores of $B_P N_n FN$.

$$\left(\begin{array}{c} le_1 t_{ij}^+ = \frac{l_{ij}^+}{1 + l_{ij}^+ - k_{ij}^+}, le_2 t_{ij}^+ = \frac{m_{ij}^+}{1 + m_{ij}^+ - l_{ij}^+}, le_3 t_{ij}^+ = \frac{n_{ij}^+}{1 + n_{ij}^+ - m_{ij}^+}, \\ le_4 t_{ij}^+ = \frac{o_{ij}^+}{1 + o_{ij}^+ - n_{ij}^+}, ri_1 t_{ij}^+ = \frac{p_{ij}^+}{1 + p_{ij}^+ - o_{ij}^+}, ri_2 t_{ij}^+ = \frac{q_{ij}^+}{1 + q_{ij}^+ - p_{ij}^+}, \\ ri_3 t_{ij}^+ = \frac{r_{ij}^+}{1 + r_{ij}^+ - q_{ij}^+}, ri_4 t_{ij}^+ = \frac{s_{ij}^+}{1 + s_{ij}^+ - r_{ij}^+} \end{array} \right)$$





$$\left(\begin{aligned} le_1 t_{ij}^- &= \frac{l_{ij}^-}{1+l_{ij}^- - k_{ij}^-}, le_2 t_{ij}^- = \frac{m_{ij}^-}{1+m_{ij}^- - l_{ij}^-}, le_3 t_{ij}^- = \frac{n_{ij}^-}{1+n_{ij}^- - m_{ij}^-}, \\ le_4 t_{ij}^- &= \frac{o_{ij}^-}{1+o_{ij}^- - n_{ij}^-}, ri_1 t_{ij}^- = \frac{p_{ij}^-}{1+p_{ij}^- - o_{ij}^-}, ri_2 t_{ij}^- = \frac{q_{ij}^-}{1+q_{ij}^- - p_{ij}^-}, \\ ri_3 t_{ij}^- &= \frac{r_{ij}^-}{1+r_{ij}^- - q_{ij}^-}, ri_4 t_{ij}^- = \frac{s_{ij}^-}{1+s_{ij}^- - r_{ij}^-} \end{aligned} \right)$$

Step 3(a): The total of the normalization scores should be calculated as follows:

$$\left(\begin{aligned} \beta_{ij1}^+ &= \frac{le_1 t_{ij}^+ (1 - le_1 t_{ij}^+) + (le_2 t_{ij}^+)^2}{1 - le_1 t_{ij}^+ + le_2 t_{ij}^+}, \beta_{ij2}^+ = \frac{le_2 t_{ij}^+ (1 - le_2 t_{ij}^+) + (le_3 t_{ij}^+)^2}{1 - le_2 t_{ij}^+ + le_3 t_{ij}^+}, \\ \beta_{ij3}^+ &= \frac{le_3 t_{ij}^+ (1 - le_3 t_{ij}^+) + (le_4 t_{ij}^+)^2}{1 - le_3 t_{ij}^+ + le_4 t_{ij}^+}, \beta_{ij4}^+ = \frac{le_4 t_{ij}^+ (1 - le_4 t_{ij}^+) + (ri_1 t_{ij}^+)^2}{1 - le_4 t_{ij}^+ + ri_1 t_{ij}^+}, \\ \beta_{ij5}^+ &= \frac{ri_1 t_{ij}^+ (1 - ri_1 t_{ij}^+) + (ri_2 t_{ij}^+)^2}{1 - ri_1 t_{ij}^+ + ri_2 t_{ij}^+}, \beta_{ij6}^+ = \frac{ri_2 t_{ij}^+ (1 - ri_2 t_{ij}^+) + (ri_3 t_{ij}^+)^2}{1 - ri_2 t_{ij}^+ + ri_3 t_{ij}^+}, \\ \beta_{ij7}^+ &= \frac{ri_3 t_{ij}^+ (1 - ri_3 t_{ij}^+) + (ri_4 t_{ij}^+)^2}{1 - ri_3 t_{ij}^+ + ri_4 t_{ij}^+} \end{aligned} \right)$$

$$\left(\begin{aligned} \beta_{ij1}^- &= \frac{le_1 t_{ij}^- (1 - le_1 t_{ij}^-) + (le_2 t_{ij}^-)^2}{1 - le_1 t_{ij}^- + le_2 t_{ij}^-}, \beta_{ij2}^- = \frac{le_2 t_{ij}^- (1 - le_2 t_{ij}^-) + (le_3 t_{ij}^-)^2}{1 - le_2 t_{ij}^- + le_3 t_{ij}^-}, \\ \beta_{ij3}^- &= \frac{le_3 t_{ij}^- (1 - le_3 t_{ij}^-) + (le_4 t_{ij}^-)^2}{1 - le_3 t_{ij}^- + le_4 t_{ij}^-}, \beta_{ij4}^- = \frac{le_4 t_{ij}^- (1 - le_4 t_{ij}^-) + (ri_1 t_{ij}^-)^2}{1 - le_4 t_{ij}^- + ri_1 t_{ij}^-}, \\ \beta_{ij5}^- &= \frac{ri_1 t_{ij}^- (1 - ri_1 t_{ij}^-) + (ri_2 t_{ij}^-)^2}{1 - ri_1 t_{ij}^- + ri_2 t_{ij}^-}, \beta_{ij6}^- = \frac{ri_2 t_{ij}^- (1 - ri_2 t_{ij}^-) + (ri_3 t_{ij}^-)^2}{1 - ri_2 t_{ij}^- + ri_3 t_{ij}^-}, \\ \beta_{ij7}^- &= \frac{ri_3 t_{ij}^- (1 - ri_3 t_{ij}^-) + (ri_4 t_{ij}^-)^2}{1 - ri_3 t_{ij}^- + ri_4 t_{ij}^-} \end{aligned} \right)$$

Step 3(b): The total of the normalization scores should be calculated as follows.

$$\left(\begin{aligned} \beta_{ij1@}^+ &= \frac{\beta_{ij1}^+ (1 - \beta_{ij1}^+) + (\beta_{ij2}^+)^2}{1 - \beta_{ij1}^+ + \beta_{ij2}^+}, \beta_{ij2@}^+ = \frac{\beta_{ij2}^+ (1 - \beta_{ij2}^+) + (\beta_{ij3}^+)^2}{1 - \beta_{ij2}^+ + \beta_{ij3}^+}, \\ \beta_{ij3@}^+ &= \frac{\beta_{ij3}^+ (1 - \beta_{ij3}^+) + (\beta_{ij4}^+)^2}{1 - \beta_{ij3}^+ + \beta_{ij4}^+}, \beta_{ij4@}^+ = \frac{\beta_{ij4}^+ (1 - \beta_{ij4}^+) + (\beta_{ij5}^+)^2}{1 - \beta_{ij4}^+ + \beta_{ij5}^+}, \\ \beta_{ij5@}^+ &= \frac{\beta_{ij5}^+ (1 - \beta_{ij5}^+) + (\beta_{ij6}^+)^2}{1 - \beta_{ij5}^+ + \beta_{ij6}^+}, \beta_{ij6@}^+ = \frac{\beta_{ij6}^+ (1 - \beta_{ij6}^+) + (\beta_{ij7}^+)^2}{1 - \beta_{ij6}^+ + \beta_{ij7}^+} \end{aligned} \right)$$

$$\left(\begin{aligned} \beta_{ij1@}^- &= \frac{\beta_{ij1}^- (1 - \beta_{ij1}^-) + (\beta_{ij2}^-)^2}{1 - \beta_{ij1}^- + \beta_{ij2}^-}, \beta_{ij2@}^- = \frac{\beta_{ij2}^- (1 - \beta_{ij2}^-) + (\beta_{ij3}^-)^2}{1 - \beta_{ij2}^- + \beta_{ij3}^-}, \\ \beta_{ij3@}^- &= \frac{\beta_{ij3}^- (1 - \beta_{ij3}^-) + (\beta_{ij4}^-)^2}{1 - \beta_{ij3}^- + \beta_{ij4}^-}, \beta_{ij4@}^- = \frac{\beta_{ij4}^- (1 - \beta_{ij4}^-) + (\beta_{ij5}^-)^2}{1 - \beta_{ij4}^- + \beta_{ij5}^-}, \\ \beta_{ij5@}^- &= \frac{\beta_{ij5}^- (1 - \beta_{ij5}^-) + (\beta_{ij6}^-)^2}{1 - \beta_{ij5}^- + \beta_{ij6}^-}, \beta_{ij6@}^- = \frac{\beta_{ij6}^- (1 - \beta_{ij6}^-) + (\beta_{ij7}^-)^2}{1 - \beta_{ij6}^- + \beta_{ij7}^-} \end{aligned} \right)$$





Step 3(c): The total of the normalization scores should be calculated as follows.

$$\left(\begin{array}{l} \beta_{ij1\#}^+ = \frac{\beta_{ij1\oplus}^+(1 - \beta_{ij1\oplus}^+) + (\beta_{ij2\oplus}^+)^2}{1 - \beta_{ij1\oplus}^+ + \beta_{ij2\oplus}^+}, \beta_{ij2\#}^+ = \frac{\beta_{ij2\oplus}^+(1 - \beta_{ij2\oplus}^+) + (\beta_{ij3\oplus}^+)^2}{1 - \beta_{ij2\oplus}^+ + \beta_{ij3\oplus}^+}, \\ \beta_{ij3\#}^+ = \frac{\beta_{ij3\oplus}^+(1 - \beta_{ij3\oplus}^+) + (\beta_{ij4\oplus}^+)^2}{1 - \beta_{ij3\oplus}^+ + \beta_{ij4\oplus}^+}, \beta_{ij4\#}^+ = \frac{\beta_{ij4\oplus}^+(1 - \beta_{ij4\oplus}^+) + (\beta_{ij5\oplus}^+)^2}{1 - \beta_{ij4\oplus}^+ + \beta_{ij5\oplus}^+}, \\ \beta_{ij5\#}^+ = \frac{\beta_{ij5\oplus}^+(1 - \beta_{ij5\oplus}^+) + (\beta_{ij6\oplus}^+)^2}{1 - \beta_{ij5\oplus}^+ + \beta_{ij6\oplus}^+} \\ \beta_{ij1\#}^- = \frac{\beta_{ij1\oplus}^-(1 - \beta_{ij1\oplus}^-) + (\beta_{ij2\oplus}^-)^2}{1 - \beta_{ij1\oplus}^- + \beta_{ij2\oplus}^-}, \beta_{ij2\#}^- = \frac{\beta_{ij2\oplus}^-(1 - \beta_{ij2\oplus}^-) + (\beta_{ij3\oplus}^-)^2}{1 - \beta_{ij2\oplus}^- + \beta_{ij3\oplus}^-}, \\ \beta_{ij3\#}^- = \frac{\beta_{ij3\oplus}^-(1 - \beta_{ij3\oplus}^-) + (\beta_{ij4\oplus}^-)^2}{1 - \beta_{ij3\oplus}^- + \beta_{ij4\oplus}^-}, \beta_{ij4\#}^- = \frac{\beta_{ij4\oplus}^-(1 - \beta_{ij4\oplus}^-) + (\beta_{ij5\oplus}^-)^2}{1 - \beta_{ij4\oplus}^- + \beta_{ij5\oplus}^-}, \\ \beta_{ij5\#}^- = \frac{\beta_{ij5\oplus}^-(1 - \beta_{ij5\oplus}^-) + (\beta_{ij6\oplus}^-)^2}{1 - \beta_{ij5\oplus}^- + \beta_{ij6\oplus}^-} \end{array} \right)$$

Step 3(d): The total of the normalization scores should be calculated as follows.

$$\left(\begin{array}{l} \beta_{ij1\$}^+ = \frac{\beta_{ij1\#}^+(1 - \beta_{ij1\#}^+) + (\beta_{ij2\$}^+)^2}{1 - \beta_{ij1\#}^+ + \beta_{ij2\$}^+}, \beta_{ij2\$}^+ = \frac{\beta_{ij2\#}^+(1 - \beta_{ij2\#}^+) + (\beta_{ij3\$}^+)^2}{1 - \beta_{ij2\#}^+ + \beta_{ij3\$}^+}, \\ \beta_{ij3\$}^+ = \frac{\beta_{ij3\#}^+(1 - \beta_{ij3\#}^+) + (\beta_{ij4\$}^+)^2}{1 - \beta_{ij3\#}^+ + \beta_{ij4\$}^+}, \beta_{ij4\$}^+ = \frac{\beta_{ij4\#}^+(1 - \beta_{ij4\#}^+) + (\beta_{ij5\$}^+)^2}{1 - \beta_{ij4\#}^+ + \beta_{ij5\$}^+}, \\ \beta_{ij1\$}^- = \frac{\beta_{ij1\#}^-(1 - \beta_{ij1\#}^-) + (\beta_{ij2\$}^-)^2}{1 - \beta_{ij1\#}^- + \beta_{ij2\$}^-}, \beta_{ij2\$}^- = \frac{\beta_{ij2\#}^-(1 - \beta_{ij2\#}^-) + (\beta_{ij3\$}^-)^2}{1 - \beta_{ij2\#}^- + \beta_{ij3\$}^-}, \\ \beta_{ij3\$}^- = \frac{\beta_{ij3\#}^-(1 - \beta_{ij3\#}^-) + (\beta_{ij4\$}^-)^2}{1 - \beta_{ij3\#}^- + \beta_{ij4\$}^-}, \beta_{ij4\$}^- = \frac{\beta_{ij4\#}^-(1 - \beta_{ij4\#}^-) + (\beta_{ij5\$}^-)^2}{1 - \beta_{ij4\#}^- + \beta_{ij5\$}^-} \end{array} \right)$$

Step 3(e): The total of the normalization scores should be calculated as follows.

$$\left(\begin{array}{l} \beta_{ij1\$}^+ = \frac{\beta_{ij1\$}^+(1 - \beta_{ij1\$}^+) + (\beta_{ij2\$}^+)^2}{1 - \beta_{ij1\$}^+ + \beta_{ij2\$}^+}, \beta_{ij2\$}^+ = \frac{\beta_{ij2\$}^+(1 - \beta_{ij2\$}^+) + (\beta_{ij3\$}^+)^2}{1 - \beta_{ij2\$}^+ + \beta_{ij3\$}^+}, \\ \beta_{ij3\$}^+ = \frac{\beta_{ij3\$}^+(1 - \beta_{ij3\$}^+) + (\beta_{ij4\$}^+)^2}{1 - \beta_{ij3\$}^+ + \beta_{ij4\$}^+} \\ \beta_{ij1\$}^- = \frac{\beta_{ij1\$}^-(1 - \beta_{ij1\$}^-) + (\beta_{ij2\$}^-)^2}{1 - \beta_{ij1\$}^- + \beta_{ij2\$}^-}, \beta_{ij2\$}^- = \frac{\beta_{ij2\$}^-(1 - \beta_{ij2\$}^-) + (\beta_{ij3\$}^-)^2}{1 - \beta_{ij2\$}^- + \beta_{ij3\$}^-}, \\ \beta_{ij3\$}^- = \frac{\beta_{ij3\$}^-(1 - \beta_{ij3\$}^-) + (\beta_{ij4\$}^-)^2}{1 - \beta_{ij3\$}^- + \beta_{ij4\$}^-} \end{array} \right)$$

Step 3(f): The total of the normalization scores should be calculated as follows.

$$\left(\begin{array}{l} \beta_{ij1\%}^+ = \frac{\beta_{ij1\$}^+(1 - \beta_{ij1\$}^+) + (\beta_{ij2\$}^+)^2}{1 - \beta_{ij1\$}^+ + \beta_{ij2\$}^+}, \beta_{ij2\%}^+ = \frac{\beta_{ij2\$}^+(1 - \beta_{ij2\$}^+) + (\beta_{ij3\$}^+)^2}{1 - \beta_{ij2\$}^+ + \beta_{ij3\$}^+}, \\ \beta_{ij1\%}^- = \frac{\beta_{ij1\$}^-(1 - \beta_{ij1\$}^-) + (\beta_{ij2\$}^-)^2}{1 - \beta_{ij1\$}^- + \beta_{ij2\$}^-}, \beta_{ij2\%}^- = \frac{\beta_{ij2\$}^-(1 - \beta_{ij2\$}^-) + (\beta_{ij3\$}^-)^2}{1 - \beta_{ij2\$}^- + \beta_{ij3\$}^-} \end{array} \right)$$

Step 3(g): The total of the normalization scores should be calculated as follows.

$$\left(\beta_{ij1\&}^+ = \frac{\beta_{ij1\%}^+(1 - \beta_{ij1\%}^+) + (\beta_{ij2\%}^+)^2}{1 - \beta_{ij1\%}^+ + \beta_{ij2\%}^+} \right) \left(\beta_{ij1\&}^- = \frac{\beta_{ij1\%}^-(1 - \beta_{ij1\%}^-) + (\beta_{ij2\%}^-)^2}{1 - \beta_{ij1\%}^- + \beta_{ij2\%}^-} \right)$$





Step 4: $B_p N_n F$ separating values.

$$(s_{ij}^+ = (\min(k_{ij}^+) + \beta_{ij1}^+ \times \Delta_{min}^{max})) (s_{ij}^- = (\min(k_{ij}^-) + \beta_{ij1}^- \times \Delta_{min}^{max}))$$

3.2 The proposed integration of $B_p N_n F$ -PSI with CoCoSo, MOORA, WASPAS

The methodologies that have been introduced simplify the examination of a particular subset of criteria and alternatives. Additionally, it provides versatile capabilities for managing both qualitative and quantitative data. The methodical assessment of all contradictory criteria is the focus of this investigation. The agreement among numerous options and criteria is demonstrated by the comprehensive validation of extensive data metrics.

3.2.1 Method $IB_p N_n F$ PSI-CoCoSo

The first proposed method consists of explicit steps like follows:

Step 1: Select from the available options and criteria. The suitable collection of options $\mathcal{P} = \{\mathcal{P}^1, \mathcal{P}^2, \dots, \mathcal{P}^m\}$ and criteria $\mathcal{S} = \{\mathcal{S}^1, \mathcal{S}^2, \dots, \mathcal{S}^n\}$ are formulated according to the opinions of the decision-makers $\mathcal{Q} = \{\mathcal{Q}^1, \mathcal{Q}^2, \dots, \mathcal{Q}^f\}$.

Step 2: The linguistic decision matrices are constructed from the perspective of the decision makers. The matrix clarifies the correlation between the different options and given criteria. The Linguistic converting scale was used to map the linguistic matrix into a bipolar nonagonal fuzzy matrix $B_p N_n FM$.

$$\mathcal{D}^M = [\mathcal{d}_{ij}^r] = \begin{pmatrix} \mathcal{d}_{11}^r & \dots & \mathcal{d}_{1n}^r \\ \vdots & \ddots & \vdots \\ \mathcal{d}_{m1}^r & \dots & \mathcal{d}_{mn}^r \end{pmatrix} \quad (1)$$

Where $\mathcal{D}^M = [\mathcal{d}_{ij}^r] = ((k_{ij}^+, l_{ij}^+, m_{ij}^+, n_{ij}^+, o_{ij}^+, p_{ij}^+, q_{ij}^+, r_{ij}^+, s_{ij}^+) (k_{ij}^-, l_{ij}^-, m_{ij}^-, n_{ij}^-, o_{ij}^-, p_{ij}^-, q_{ij}^-, r_{ij}^-, s_{ij}^-))$; where $i = 1, 2, \dots, m, j = 1, 2, \dots, n, r = 1, 2, \dots, f$.

Step 3: Construct the $B_p N_n FM$ results. The $B_p N_n FM$ are consolidated into a sole matrix, which integrates the performance of options and criteria from several decision matrices into a unified matrix.

$$\begin{aligned} k_{ij}^+ &= k_{ij}^- = \min(k_{ij}^r), l_{ij}^+ = l_{ij}^- = \min(l_{ij}^r), m_{ij}^+ = m_{ij}^- = \min(m_{ij}^r), n_{ij}^+ = n_{ij}^- = \min(n_{ij}^r), \\ o_{ij}^+ &= o_{ij}^- = \frac{1}{r}(o_{ij}^r), p_{ij}^+ = p_{ij}^- = \max(p_{ij}^r), q_{ij}^+ = q_{ij}^- = \max(q_{ij}^r), r_{ij}^+ = r_{ij}^- = \max(r_{ij}^r), \\ s_{ij}^+ &= s_{ij}^- = \max(s_{ij}^r) \end{aligned} \quad (2)$$

Step 4: Construct the defuzzified matrix using the proposed $CB_p N_n FCS$ algorithm, which is describe in subsection 3.1.

$$\mathfrak{N} = [n_{ij}] = \begin{pmatrix} n_{11} & \dots & n_{1n} \\ \vdots & \ddots & \vdots \\ n_{m1} & \dots & n_{mn} \end{pmatrix} \quad (3)$$

where $[n_{ij}] = (n_{ij}^+, n_{ij}^-); i = 1, 2, \dots, m, j = 1, 2, \dots, n$

Step 5: Normalization the bipolar decision matrix using the formula,

$$(\mathcal{E}_{ij}^+, \mathcal{E}_{ij}^-) = \left(\frac{e_{ij}^+}{e_{ij}^{+max}}, \frac{e_{ij}^-}{e_{ij}^{-max}} \right) \text{ for beneficial attribute. (4)}$$

$$(\mathcal{E}_{ij}^+, \mathcal{E}_{ij}^-) = \left(\frac{e_{ij}^{+min}}{e_{ij}^-}, \frac{e_{ij}^{-min}}{e_{ij}^-} \right) \text{ for non beneficial attribute. (5)}$$

where $i = 1, 2, \dots, m, j = 1, 2, \dots, n$,

Step 6: Compute bipolar preference variation value,

$$B^+ P v_j = \sum_{i=1}^N (\mathcal{E}_{ij}^+ - \mathcal{E}_j^+)^2 \quad (6)$$

where \mathcal{E}_j^+ is the mean of normalized value of attribute j and $\mathcal{E}_j^+ = \frac{1}{n} \sum_{i=1}^N \mathcal{E}_{ij}^+$

$$B^- P v_j = \sum_{i=1}^N (\mathcal{E}_{ij}^- - \mathcal{E}_j^-)^2 \quad (7)$$

where \mathcal{E}_j^- is the mean of normalized value of attribute j and $\mathcal{E}_j^- = \frac{1}{n} \sum_{i=1}^N \mathcal{E}_{ij}^-$





Step 7: Determine bipolar weight of overall preference ,

$$(\psi_j^+, \psi_j^-) = \left(\frac{Q_j^+}{\sum_{j=1}^m Q_j^+}, \frac{Q_j^-}{\sum_{j=1}^m Q_j^-} \right) \quad (8)$$

where $(Q_j^+, Q_j^-) = ((1 - B^+ P v_j), (1 - B^- P v_j))$

Step 8: Normalized the bipolar defuzzied matrix using the formula:

$$(c_{ij}^+, c_{ij}^-) = \left(\frac{z_{ij}^+ - \min z_{ij}^+}{\max z_{ij}^+ - \min z_{ij}^+}, \frac{z_{ij}^- - \min z_{ij}^-}{\max z_{ij}^- - \min z_{ij}^-} \right) \text{for beneficial attribute.} \quad (9)$$

$$(c_{ij}^+, c_{ij}^-) = \left(\frac{\max z_{ij}^+ - z_{ij}^+}{\max z_{ij}^+ - \min z_{ij}^+}, \frac{\max z_{ij}^- - z_{ij}^-}{\max z_{ij}^- - \min z_{ij}^-} \right) \text{for non beneficial attribute.} \quad (10)$$

Where $i = 1, 2, \dots, m, j = 1, 2, \dots, n$,

Step 9: The bipolar of the overall weighted comparability sequence and the bipolar of the power weight of the comparability sequences for each option are as follows (Z_i^+, Z_i^-) and (Y_i^+, Y_i^-) ,

$$(Z_i^+, Z_i^-) = (\sum_{j=1}^m \dot{W}_j c_{ij}^+, (\sum_{j=1}^m \dot{W}_j c_{ij}^-)) \quad (11)$$

$$(Y_i^+, Y_i^-) = (\sum_{j=1}^n c_{ij}^+ \dot{W}_j, (\sum_{j=1}^n c_{ij}^- \dot{W}_j)) \quad (12)$$

Where $i = 1, 2, \dots, m, j = 1, 2, \dots, n$,

Step 10: The relative weights of the options are calculated using the aggregation algorithms described below. In this stage, three bipolar appraisal score procedures are employed to establish relative weights for additional options, which are derived using Formulas (13)– (15):

$$(K_{ia}^+, K_{ia}^-) = \left(\frac{Y_i^+ + Z_i^+}{\sum_{j=1}^m (Y_j^+ + Z_j^+)}, \frac{Y_i^- + Z_i^-}{\sum_{j=1}^m (Y_j^- + Z_j^-)} \right) \quad (13)$$

$$(K_{ib}^+, K_{ib}^-) = \left(\frac{Z_i^+}{\min Z_i^+} + \frac{Y_i^+}{\min Y_i^+}, \frac{Z_i^-}{\min Z_i^-} + \frac{Y_i^-}{\min Y_i^-} \right) \quad (14)$$

$$(K_{ic}^+, K_{ic}^-) = \left(\frac{\lambda Z_i^+ + (1-\lambda) Y_i^+}{\lambda \max Z_i^+ + (1-\lambda) \max Y_i^+}, \frac{\lambda Z_i^- + (1-\lambda) Y_i^-}{\lambda \max Z_i^- + (1-\lambda) \max Y_i^-} \right) \quad 0 \leq \lambda \leq 1 \quad (15)$$

Step 11: To calculate the value (K_i^+, K_i^-) using the value (K_{ia}^+, K_{ia}^-) , (K_{ib}^+, K_{ib}^-) and (K_{ic}^+, K_{ic}^-)

$$(K_i^+, K_i^-) = \left(\left((K_{ia}^+ K_{ib}^+ K_{ic}^+)^{\frac{1}{3}} + \frac{1}{3} (K_{ia}^+ + K_{ib}^+ + K_{ic}^+) \right), \left((K_{ia}^- K_{ib}^- K_{ic}^-)^{\frac{1}{3}} + \frac{1}{3} (K_{ia}^- + K_{ib}^- + K_{ic}^-) \right) \right) \quad (16)$$

Step 12: The final score of each alternative is obtained using this Equation (17)

$$\mathcal{K}_i = \left(\frac{1 + K_i^+ K_i^-}{2} \right) \quad (17)$$

Establish the rank order of the options.

3.2.2 Method II: $B_p N_n F$ PSI-MOORA:

Using the first seven step are the same as section 3.2.1.

Step 8: Normalized bipolar decision matrix:

$$(X_{ij}^+, X_{ij}^-) = \left(\frac{x_{ij}^+}{(\sum_{j=1}^m x_{ij}^{+2})^{\frac{1}{2}}}, \frac{x_{ij}^-}{(\sum_{j=1}^m x_{ij}^{-2})^{\frac{1}{2}}} \right) \quad (18)$$

Where $(i = 1, 2, \dots, m, j = 1, 2, \dots, n)$.

Step 9: Compute the equation for bipolar estimate of assessment values.,

$$(\mathcal{A}_i^+, \mathcal{A}_i^-) = \left(\frac{\sum_{j=1}^l \psi_j^+ (X_{ij}^+) - \sum_{j=l+1}^n \psi_j^+ (X_{ij}^+)}{\sum_{j=1}^l \psi_j^- (X_{ij}^-) - \sum_{j=l+1}^n \psi_j^- (X_{ij}^-)} \right), j = 1, 2, \dots, n. \quad (19)$$





Step 10: Using this Equation, the ultimate score of each possibility is calculated.

$$\mathcal{A}_i = \left(\frac{1 + \mathcal{A}_i^+ - \mathcal{A}_i^-}{2} \right) \quad (20)$$

Establish the rank order of the options.

3.2.3 Method III: $B_P N_n F$ PSI -WASPAS:

Using the first seven step are the same as section 3.2.1.

Step 8: Determine the overall significance by calculating the bipolar total relative importance for weight sum model,

$$\left(\mathbb{Q}_i^{B_P^+ WSM}, \mathbb{Q}_i^{B_P^- WSM} \right) = \left(\sum_{j=1}^n \mathcal{W}_j^+ \mathbb{Q}_{ij}^+, \sum_{j=1}^n \mathcal{W}_j^- \mathbb{Q}_{ij}^- \right) \quad (21)$$

Step 9: Determine the overall significance by calculating the bipolar total relative importance for weight product model,

$$\left(\mathbb{Q}_i^{B_P^+ WPM}, \mathbb{Q}_i^{B_P^- WPM} \right) = \left(\prod_{j=1}^n \mathbb{Q}_{ij}^{+\mathcal{W}_j^+}, \prod_{j=1}^n \mathbb{Q}_{ij}^{-\mathcal{W}_j^-} \right) \quad (22)$$

Step 10: Calculate the bipolar preference score value obtained by below formula

$$\left(\mathbb{Q}_i^{B_P^+}, \mathbb{Q}_i^{B_P^-} \right) = \left(\frac{\left(\lambda \mathbb{Q}_i^{B_P^+ WSM} + (1 - \lambda) \mathbb{Q}_i^{B_P^+ WPM} \right)}{\left(\lambda \mathbb{Q}_i^{B_P^- WSM} + (1 - \lambda) \mathbb{Q}_i^{B_P^- WPM} \right)} \right) 0 \leq \lambda \leq 1 \quad (23)$$

Step 11: This Equation is used to determine the ultimate score of each possibility

$$\mathbb{Q}_i = \left(\frac{1 + \mathbb{Q}_i^{B_P^+} - \mathbb{Q}_i^{B_P^-}}{2} \right) \quad (24)$$

Establish the rank order of the options.

4. Illustration of medical diagnosis in liver problem using numerical data

This section focuses on the application of the $B_P N_n F$ PSI-CoCoSo, $B_P N_n F$ PSI-MOORA and $B_P N_n F$ PSI -WASPAS approach in the medical diagnosis of liver disorders. Liver-related diseases encompass a wide range of disorders that affect the structure or function of the liver, such as hepatitis, cirrhosis, fatty liver disease, and liver cancer. The model that utilizes the specified collection of linguistic values is chosen exclusively for the purpose of providing precise illustrations.

4.1 Method $B_P N_n F$ PSI-CoCoSo

Step 1: To identify patients in critical stages of liver disorders, five patients were chosen as alternatives: \mathcal{P}^1 =Patient 1; \mathcal{P}^2 = Patient 2; \mathcal{P}^3 =Patient 3; \mathcal{P}^4 =Patient 4; \mathcal{P}^5 =Patient 5. The options are evaluated based on a certain established set of criteria are \mathcal{S}^1 = Jaundice; \mathcal{S}^2 = Ascites; \mathcal{S}^3 = Hepatomegaly; \mathcal{S}^4 = Fatigue; \mathcal{S}^5 = Abnormal Liver Enzymes are recommended by decision makers $\mathcal{Q} = \{\mathcal{Q}^1, \mathcal{Q}^2, \mathcal{Q}^3\}$ and Fig 1. Alternatives and Criteria.

Step 2: The Linguistic converting scale was used to map the linguistic matrix into a bipolar nonagonal fuzzy matrix $B_P N_n FM$. Consolidate the $B_P N_n FM$ results into a single matrix, which integrates the performance of options and criteria from several decision matrices illustrated in the Equation (1) and (2). Table 1 represents the Linguistic decision matrices and Table 2 represents the linguistic variables $B_P N_n FN$.

Step 3: The $B_P N_n FM$ is transformed into a defuzzified matrix using $CB_P N_n FM$ algorithm, and the $B_P N_n FM$ is converted into a crisp number, the value give in table 3

Step 4: Normalized the bipolar defuzzified matrix using the formula (9) and (10). The bipolar of the overall weighted comparability sequence and the bipolar of the power weight of the comparability sequences for each option are as follows (Z_i^+, Z_i^-) and (Y_i^+, Y_i^-) using the equation (11) and (12). The bipolar weight is calculating the $B_P N_n F$ PSI using the equation (8) the value represents in table 4.





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Step 5: Bipolar aggregation of appraisal score strategies (13), (14) and (15) and $\lambda = 0.5$. Then get the value of (K_{ia}^+, K_{ia}^-) , (K_{ib}^+, K_{ib}^-) , (K_{ic}^+, K_{ic}^-) . We apply these values in equation (16) we find (K_i^+, K_i^-)

Step 6: To categorize the possibilities, organize them in order of descending based on their numerical values of Equation (17) and find the final outcome of $B_p N_n F$ PSI-CoCoSo are represented in Table 5.

4.2 Method II $B_p N_n F$ PSI-MOORA:

The first 3 steps are the same as the method I.

Step 4: Normalize bipolar decision matrix for $B_p N_n F$ PSI-MOORA method using the equation (18) and evaluate the equation for estimation of assessment values using the equation (19)

Step 5: To categorize the possibilities, organize them in order of descending based on their numerical values of Equation (20) and find the final outcome of $B_p N_n F$ PSI-MOORA. Table 6 represents ranking of $B_p N_n F$ PSI-MOORA and Figure 3 represents the final score of $B_p N_n F$ PSI-MOORA method.

4.3 Method III $B_p N_n F$ PSI-WASPAS:

The first 3 steps are the same as the method I.

Step 4: Normalize bipolar decision matrix for $B_p N_n F$ PSI-WASPAS and Determine the overall significance by calculating the bipolar total relative importance for weight sum model using the equation (21).

Step 5: Determine the overall significance by calculating the bipolar total relative importance for weight product model using the equation (22) and calculate the bipolar preference score value obtained using the equation (23).

Step 6: To categorize the possibilities, organize them in order of descending based on their numerical values of Equation (24) and find the final outcome of $B_p N_n F$ PSI-WASPAS. Table 7 represents ranking of $B_p N_n F$ PSI-WASPAS and Figure 4 represents the final score of $B_p N_n F$ PSI-WASPAS method.

CONCLUSION

The goal of this study is to develop an integrated $B_p N_n F$ -PSI with $B_p N_n F$ -CoCoSo and $B_p N_n F$ -MOORA and $B_p N_n F$ -WASPAS to investigate the symptoms of jaundice, ascites, hepatomegaly, fatigue, and abnormal liver enzymes in five individuals with liver disorders. Upon careful examination of the final outcome of the fuzzy integrated MCDM method approach, it has been determined that patient 1 is in a critical phase of liver disease. Further investigation is required to determine the most ideal and accurate results obtained from the test used for diagnosing liver disorders.

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Table.1: represents the Linguistic decision matrices.

Decision makers		S^1	S^2	S^3	S^4	S^5
Q^1	P^1	\aleph^5	\aleph^5	\aleph^5	\aleph^5	\aleph^5
	P^2	\aleph^4	\aleph^3	\aleph^3	\aleph^4	\aleph^4
	P^3	\aleph^3	\aleph^2	\aleph^2	\aleph^3	\aleph^3
	P^4	\aleph^4	\aleph^4	\aleph^2	\aleph^4	\aleph^3





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	\mathcal{P}^5	\aleph^3	\aleph^2	\aleph^3	\aleph^1	\aleph^3
	\mathcal{P}^1	\aleph^5	\aleph^5	\aleph^5	\aleph^3	\aleph^4
\mathcal{Q}^2	\mathcal{P}^2	\aleph^4	\aleph^4	\aleph^3	\aleph^4	\aleph^4
	\mathcal{P}^3	\aleph^3	\aleph^3	\aleph^2	\aleph^1	\aleph^3
	\mathcal{P}^4	\aleph^4	\aleph^4	\aleph^4	\aleph^4	\aleph^3
	\mathcal{P}^5	\aleph^3	\aleph^3	\aleph^3	\aleph^3	\aleph^3
	\mathcal{P}^1	\aleph^4	\aleph^3	\aleph^5	\aleph^4	\aleph^3
\mathcal{Q}^3	\mathcal{P}^2	\aleph^5	\aleph^5	\aleph^5	\aleph^2	\aleph^4
	\mathcal{P}^3	\aleph^3	\aleph^3	\aleph^3	\aleph^3	\aleph^2
	\mathcal{P}^4	\aleph^4	\aleph^5	\aleph^5	\aleph^3	\aleph^4
	\mathcal{P}^5	\aleph^2	\aleph^1	\aleph^3	\aleph^2	\aleph^3

Table.2: represents the linguistic variables $B_P N_n$ FN.

Linguistic variable	Bipolar Nonagonal fuzzy number
\aleph^1 - Very low	(0.00, 0.01, 0.03, 0.06, 0.09, 0.12, 0.15, 0.18, 0.20), (0.78, 0.80, 0.83, 0.86, 0.89, 0.92, 0.95, 0.98, 1.00)
\aleph^2 - Low	(0.18, 0.20, 0.23, 0.26, 0.29, 0.32, 0.35, 0.38, 0.40), (0.58, 0.60, 0.63, 0.66, 0.69, 0.72, 0.75, 0.78, 0.80)
\aleph^3 - Medium	(0.38, 0.40, 0.43, 0.46, 0.49, 0.52, 0.55, 0.58, 0.60), (0.38, 0.40, 0.43, 0.46, 0.49, 0.52, 0.55, 0.58, 0.60)
\aleph^4 - High	(0.58, 0.60, 0.63, 0.66, 0.69, 0.72, 0.75, 0.78, 0.80), (0.18, 0.20, 0.23, 0.26, 0.29, 0.32, 0.35, 0.38, 0.40)
\aleph^5 - Very high	(0.78, 0.80, 0.83, 0.86, 0.89, 0.92, 0.95, 0.98, 1.00), (0.00, 0.01, 0.03, 0.06, 0.09, 0.12, 0.15, 0.18, 0.20)

Table.3: Represents bipolar defuzzied matrix

	\mathcal{S}^1	\mathcal{S}^2	\mathcal{S}^3	\mathcal{S}^4	\mathcal{S}^5
\mathcal{P}^1	(0.948599, 0.028854)	(0.923768, 0.047286)	(0.965246, 0.017315)	(0.905127, 0.062830)	(0.844828, 0.120488)
\mathcal{P}^2	(0.937552, 0.037772)	(0.905157, 0.062830)	(0.812811, 0.148786)	(0.510948, 0.444757)	(0.714956, 0.261767)
\mathcal{P}^3	(0.465044, 0.513100)	(0.329551, 0.637463)	(0.231401, 0.743380)	(0.062830, 0.637463)	(0.242448, 0.734956)
\mathcal{P}^4	(0.714956, 0.261767)	(0.953311, 0.025150)	(0.609123, 0.347328)	(0.658770, 0.312499)	(0.577493, 0.368725)
\mathcal{P}^5	(0.242448, 0.734956)	(0.062830, 0.905127)	(0.465044, 0.509034)	(0.062830, 0.905127)	(0.465044, 0.513100)

Table.4: represents the bipolar weight of $B_P N_n$ F PSI.

(ψ_j^+, ψ_j^-)	(0.232693, 0.152896)	(0.101289, 0.092694)	(0.25736, 0.203061)	(0.129462, 0.254010)	(0.279197, 0.297339)
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Table.5: represents the final outcome of $B_P N_n$ F PSI-CoCoSo.

Alternatives	$B_P N_n$ F PSI-CoCoSo	Final score	Ranking
\mathcal{P}^1	(6.309618, 0.931806)	3.188906	1
\mathcal{P}^2	(5.512470, 36.54794)	-15.0177	2





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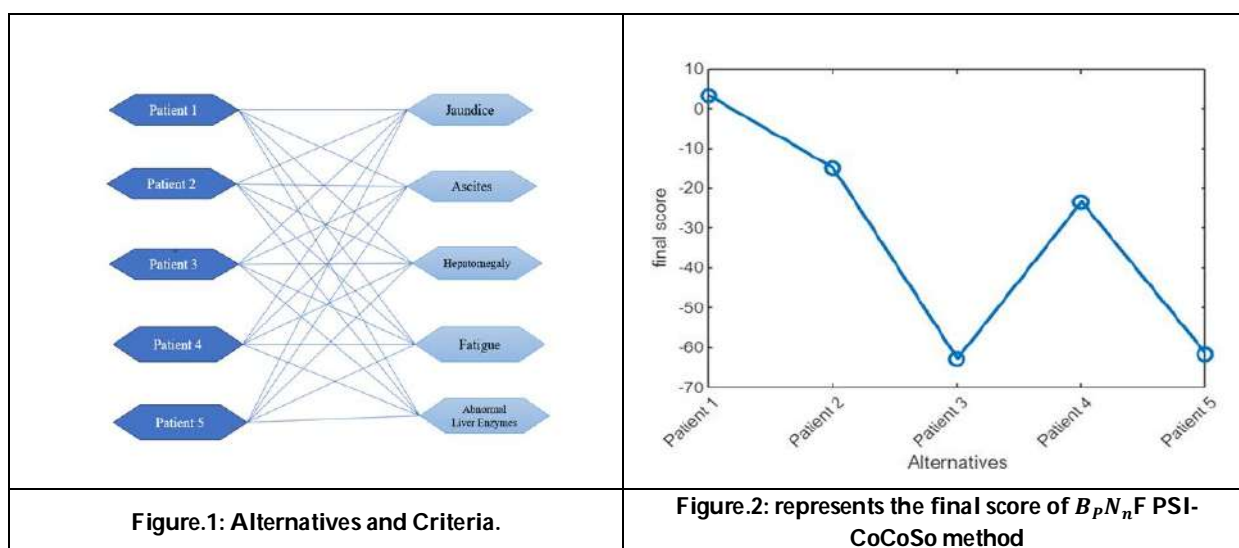
\mathcal{P}^3	(1.201778, 127.9810)	-62.8896	5
\mathcal{P}^4	(4.700310, 52.68634)	-23.493	3
\mathcal{P}^5	(1.452932, 125.6409)	-61.594	4

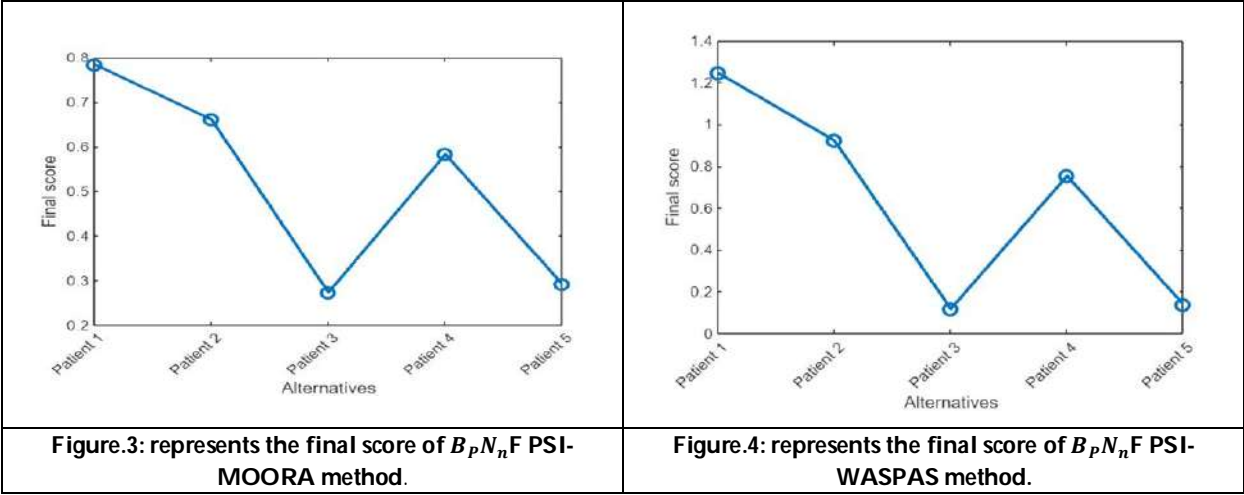
Table.6: represents the final outcome of $B_p N_n F$ PSI-MOORA.

Alternatives	$B_p N_n F$ PSI-MOORA	Final score	Ranking
\mathcal{P}^1	(0.630235, 0.060619)	0.784808	1
\mathcal{P}^2	(0.533089, 0.210799)	0.661145	2
\mathcal{P}^3	(0.184338, 0.638855)	0.272742	5
\mathcal{P}^4	(0.455808, 0.289789)	0.58301	3
\mathcal{P}^5	(0.221673, 0.638600)	0.291537	4

Table.7: represents the final outcome of $B_p N_n F$ PSI-WASPAS

Alternatives	$B_p N_n F$ PSI-WASPAS	Final score	Ranking
\mathcal{P}^1	(2.996839, 1.505071)	1.245884	1
\mathcal{P}^2	(2.842057, 1.996819)	0.922619	2
\mathcal{P}^3	(2.075575, 2.840342)	0.117616	5
\mathcal{P}^4	(2.703838, 2.197414)	0.753212	3
\mathcal{P}^5	(2.111578, 2.835440)	0.138069	4







Correlation of Dermatoglyphics and Blood Groups as a Diagnostic tool for Periodontal Status

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ABSTRACT

Dermatoglyphics, the study of the patterns of ridges on the fingers and palms, has been explored as a non-invasive method to predict genetic predispositions to various diseases, including periodontitis. Periodontitis is a multifactorial, inflammatory disease affecting the supporting structures of the teeth, leading to progressive destruction of the periodontal ligament and alveolar bone. Research suggests a potential correlation between dermatoglyphic patterns and susceptibility to periodontitis, as both are influenced by genetic factors. Dermatoglyphic markers, such as increased whorl patterns and altered ridge counts, have been observed more frequently in individuals with periodontitis, indicating a possible genetic predisposition. This study aims to establish the relationship between dermatoglyphics and periodontitis, emphasizing the potential of dermatoglyphic analysis as a predictive tool for early detection and risk assessment in periodontal disease. Though further studies are necessary to elucidate the genetic links and validate dermatoglyphics as a reliable biomarker for periodontitis.

Keywords: Research suggests a potential correlation between dermatoglyphic patterns and susceptibility to periodontitis, as both are influenced by genetic factors.



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INTRODUCTION

Periodontal disease is a chronic inflammatory disease that encompasses a range of inflammatory conditions affecting the supporting structures of the teeth. It progresses from gingivitis, a mild form of gum inflammation, to periodontitis, which can lead to tooth loss if untreated. Early detection and intervention are crucial for managing periodontal disease effectively. Dermatoglyphics is the scientific study of the patterns of ridges and lines seen on the skin of human palms, toes, fingers, and soles. The term is derived from the Greek word's "derma" meaning skin, and "glyph" meaning carving. These patterns, which include loops, whorls, and arches, are formed during fetal development and are unique to each individual, remaining unchanged throughout a person's life. Cummins and Midlo (1926) were the first to coin the term dermatoglyphics(1). Toward the close of the 19th century, Galton proposed a principle known as the "proof of no change," which asserts that a person's fingerprints remain constant throughout their life. (2). Due to their one of a kind nature, examining them can decide a number of parameters, which may well be supportive in diagnosing and treatment of inspected individuals(3). Hence, it is an critical apparatus in surveying the hereditary trait, testing of children with suspected hereditary clutters conjointly in forensics.

In 1892, Galton classified the basic fingerprint patterns of three types: arches, loops, and whorls.(4) Additionally, the palm of a human exhibits features such as the ATD angle, which is made of the lines connecting –

- A - the digital triradius
- T - the axial triradius
- D - axial triradius to the digital triradius

Other features include the H-loop, IV loop, and triradii, which are points where three ridge regions converge (5) Loops, the most common pattern, are characterized by ridges that enter from one side, create a loop, and exit from the same side. Whorls have circular or spiral patterns, while arches are the simplest, with ridges entering from one side and exiting from the opposite side without forming a loop. FIG :1Blood groups, primarily the ABO and Rh systems, are based on red blood cells and the presence of specific antigens. These antigens are genetically inherited and have been linked to various systemic conditions, including susceptibility to infections and certain diseases. Dermatoglyphics has gained attention in dentistry for its use in detecting oral diseases and disorders such as oral cancer, malocclusion, bruxism dental caries, tooth anomalies, cleft palate, cleft lip,periodontal disease, dental fluorosis, and for aiding forensic odontology in uncovering the truth. (6). Researchers have investigated the potential correlation between dermatoglyphic patterns, blood groups, and periodontal status. The hypothesis is that certain genetic markers reflected in dermatoglyphic patterns and blood groups might be associated with susceptibility to periodontal disease. The present short study was conducted to find a correlation between blood groups, dermatoglyphic patterns, and periodontal status.

Types of fingertip patterns

In 1892, Sir Francis Galton published his influential book, "Finger Prints," in which he introduced a system for classifying fingerprints based on the number of triradii, the points where three ridge lines converge. Galton's system identified three primary fingerprint patterns: arches, loops, and whorls. Arches, the simplest pattern, featuring ridges that enter from one side of the finger, rise in the center forming an arch, and exit on the opposite side without looping back. They do not contain any triradii. Loops are apropos to ridges that from one side of the finger, loop around, and exit on the same side from which they entered. Each loop pattern contains one triradius. Whorls are more complex patterns, with ridges that form circular or spiral shapes. Whorls typically have two triradii, one on either side of the pattern. Galton's work laid the foundation for the modern study of dermatoglyphics, providing a systematic approach to analyzing and classifying fingerprint patterns, which has since become a crucial tool in fields such as forensic science and personal identification. (7, 8). (Fig:2) Fig2: Galton's types of fingerprints and the lines indicating method for counting ridges. (9)





MATERIAL AND METHODS

This study was conducted in the outpatient periodontics department, involving 45 patients aged between 18 and 45 years. Participants were informed about the study details and provided their consent. The patients were categorized into three groups, each containing 15 individuals:

- Group I - Healthy control group
- Group II – Gingivitis Patients
- Group III - Chronic Periodontitis Patients

Exclusion criteria included the presence of systemic diseases and the absence of a digit. Periodontitis was evaluated using a probing pocket depth (PPD) of ≥ 5 mm and Russel's periodontal index. A comprehensive case history was recorded for each participant. During the investigation, the blood groups of all participants were determined through laboratory testing. Dermatoglyphic patterns were recorded using the standard ink method. Participants were instructed to clean their hands thoroughly to remove impurities, and spirit was used to eliminate any remaining oil and dirt. Duplicating ink was then applied to capture the fingerprints, which were subsequently examined with a magnifying lens. The patterns were classified into arches, loops, and whorls, and the periodontal status of each participant was recorded. It was found that among gingivitis, the highest prevalence was seen for whorl pattern with 43% (n=13) and lowest for loop pattern with 27% (n=08). Among periodontitis, the highest prevalence was seen for arch pattern with 47% (n=14) and lowest for whorl pattern with 23% (n=07). Among healthy controls, the highest prevalence was seen for arch pattern with 50% (n=15) and lowest for whorl pattern with 20% (n=06) ($p < 0.05^*$). (Table 1) Table 1: comparison between different patterns of thumb prints among patients with gingivitis, periodontitis and healthy controls. Among gingivitis patients with 30 thumb prints, A+ve, A-ve, B+ve, O+ve, O-ve and AB+ve were 0,6,18,4,0 and 2 respectively.

Among periodontitis patients with 30 thumb prints, A+ve, A-ve, B+ve, O+ve, O-ve and AB+ve were 10, 0, 12, 8, 0 and 0 respectively. Among healthy patients with 30 thumb prints, A+ve, A-ve, B+ve, O+ve, O-ve and AB+ve were 4,0,12,8,2 and 4 respectively. A statistically significant difference was observed between periodontal conditions and blood groups ($p < 0.05$). (Table 2 , Graph 1) Table 2 : comparison between periodontal status and blood groups Graph 1 : Comparison between periodontal status and blood groups On examination of gingivitis patients (n=15) with 30 thumb prints, loop, whorl and arch were 8, 13 and 9 respectively. On correlating this with various blood groups, it was found that for loop, A-ve, B+ve, AB+ve and O+ve the frequency observed were 2,4,2,0 while for whorl it was 2,2,0,9 and for arch it was 2,5,0 and 2. A significant difference was observed between thumb prints and blood groups ($p < 0.05$). (Table 3 ,Graph 2) Table 3 : Relationship between gingivitis ,Thumb prints and blood groups Graph 2 : Relationship between gingivitis ,Thumb prints and blood groups On examination of periodontitis patients (n=15) with 30 thumb prints, loop, whorl and arch were 9, 7 and 14 respectively. On correlating this with various blood groups, it was found that for loop, A+ve, B+ve and O+ve the frequency observed were 3,4, and 2 while for whorl it was 3,3, and 1 and for arch it was 4,7 and 3. A statistically non- significant difference was observed between thumb prints and blood groups ($p > 0.05$). (Table 4, Graph 3) Table 4: Relationship between periodontitis ,thumb prints and Blood groups Graph 3 : Relationship between periodontitis , thumb prints and Blood groups On examination of healthy patients (n=15) with 30 thumb prints, loop, whorl and arch were 9, 6 and 15 respectively. On correlating this with various blood groups, it was found that for loop, B+ve, O-ve, A+ve, AB+ve and O+ve the frequency observed were 3,1,1,1,3 while for whorl it was 1,0,3,2,0 and for arch it was 6,1,1,3,4. A statistically non- significant difference was observed between thumb prints and blood groups ($p > 0.05$). (table 5,graph 4) Table 5: Relationship between healthy controls, thumb prints and Blood groups Graph 4: Relationship between healthy controls, thumb prints and Blood groups

DISCUSSION

Dermatoglyphics, the study of the patterns of ridges on the fingers, palms, toes, and soles, has been considered as a potential diagnostic tool for various medical conditions due to its genetic basis. Blood groups, determined by the



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presence or absence of specific antigens on the surface of red blood cells, also have a genetic basis. The correlation between dermatoglyphics and blood groups and their potential use as diagnostic tools for periodontal status is an intriguing area of research. Therefore, the present study was conducted to find the association of periodontal status with ABO blood group and dermatoglyphics. Several studies have explored the relationship between dermatoglyphic patterns and periodontal disease, Kavitha *et al.* (2014)** conducted a study that found a significant association between specific dermatoglyphic patterns and periodontal disease. They observed that individuals with whorl patterns were more prone to periodontitis(10).Reddy *et al.* (2011) found that patients with periodontitis had a higher frequency of loops and arches compared to those without the disease, suggesting a potential genetic predisposition(11).The results of the present study showed higher frequency of Arches in periodontitis patients and higher frequency of Whorls in Gingivitis patients. Yilmaz *et al.* conducted a study in 1993 to examine the function of dermatoglyphics in periodontal disease. The study involved 70 patients, including 20 adults with periodontitis, 20 with early onset periodontitis cases, and 20 periodontally healthy patients. The study examined the quantitative and qualitative patterns of ridged skin. They verified that genetics plays a part in the etiopathogenesis of periodontal disorders. It was the first study in which role of dermatoglyphics in periodontal study was observed(12). Research has indicated potential links between blood groups and susceptibility to periodontal disease, Demir *et al.* (2007) found that individuals with blood group O had a higher prevalence of periodontitis compared to other blood groups(13). Nikolopoulos *et al.* (2012) reported that blood group B was associated with a higher risk of aggressive periodontitis(14). In the present study statistically significant difference was observed between periodontal conditions and blood groups. Blood group B had a higher prevalence of periodontitis as compared to the other blood groups.

CONCLUSION

The correlation of dermatoglyphics and blood groups with periodontal status holds a promising non-invasive diagnostic tool. However, more research is needed to establish these correlations and develop practical applications. If successful, this approach could enhance early detection and personalized treatment of periodontal disease, ultimately improving patient outcomes.

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Table. 1: comparison between different patterns of thumb prints among patients with gingivitis, periodontitis and healthy controls.

Thumb prints	Types	Loop, n (%)	Whorl, n (%)	Arch n (%)	χ^2	sig. (p<0.05*)
<u>Gingivitis</u>						
Total (30)	-	08 (27%)	13 (43%)	09 (30%)	16.43	<0.05*
<u>Periodontitis</u>						
Total (30)	-	09 (30%)	07 (23%)	14 (47%)	23.76	<0.05*
<u>Healthy control</u>						
Total (30)	-	09 (30%)	06 (20%)	15 (50%)	17.82	<0.05*

Table 1: Types of palmar and fingertip patterns

<i>Palmar patterns</i>	<i>Fingertip patterns</i>
<ul style="list-style-type: none"> • Thenar area (Th or I₁) • Hypothenar area (Hy) • Interdigital areas (I₂, I₃, I₄) • Palmar creases (DC, PC and TC) • Atd angle 	<ul style="list-style-type: none"> • Arches • Loops • Whorls



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Table.2 : comparison between periodontal status and blood groups

Periodontal Status	Total	A+ve	A-ve	B+ve	O+ve	O-ve	AB+ve	X ²	sig. (p<0.05*)
Gingivitis, n (%)	30 (100%)	0	6 (20)	18 (60)	4 (13)	0	2 (7)	17.23	0.02*
Periodontitis, n (%)	30 (100%)	10 (33)	0	12 (40)	8 (27)	0	0		
Healthy, n (%)	30 (100%)	4 (13)	0	12 (40)	8 (27)	2 (7)	4 (13)		
Total, n (%)	90 (100%)	14 (16)	6 (7)	32 (36)	20 (22)	2 (2)	6 (7)		

Table.3 : Relationship between gingivitis, Thumbprints and blood groups

Thumb prints	Total	A+ve	B+ve	O+ve	X ²	sig. (p<0.05*)
Loop,n (%)	9(100)	3 (33)	4 (44)	2 (23)	8.22	0.08
Whorl,n (%)	7 (100)	3 (43)	3(43)	1 (14)		
Arch(%)	14 (100)	4 (30)	7 (45)	3 (25)		
Total,n (%)	30 (100)	10 (33)	12 (40)	8 (27)		

Table.4: Relationship between periodontitis, thumbprints and Blood groups

Thumb prints	Total	A+ve	B+ve	O+ve	X ²	sig. (p<0.05*)
Loop,n (%)	9 (100)	3 (33)	4 (44)	2(23)	8.22	0.08
Whorl,n (%)	7 (100)	3(43)	3(43)	1(14)		
Arch(%)	14 (100)	4(30)	7 (45)	3(25)		
Total,n (%)	30(100)	10(33)	12(40)	8(27)		

Table.5: Relationship between healthy controls, thumbprints and Blood groups

Thumb prints	Total	B+ve	O-ve	A+ve	AB+ve	O+ve	X ²	sig. (p<0.05*)
Loop,n (%)	9 (100)	3 (34)	1 (11)	1 (11)	1 (11)	3 (34)	21.32	1.24
Whorl, n (%)	6 (100)	1 (17)	0	3 (50)	2 (33)	0		
Arch (%)	15 (100)	6 (40)	1 (7)	1 (7)	3 (20)	4 (26)		
Total,n (%)	30 (100)	12 (40)	2 (7)	4 (13)	5 (17)	7 (23)		





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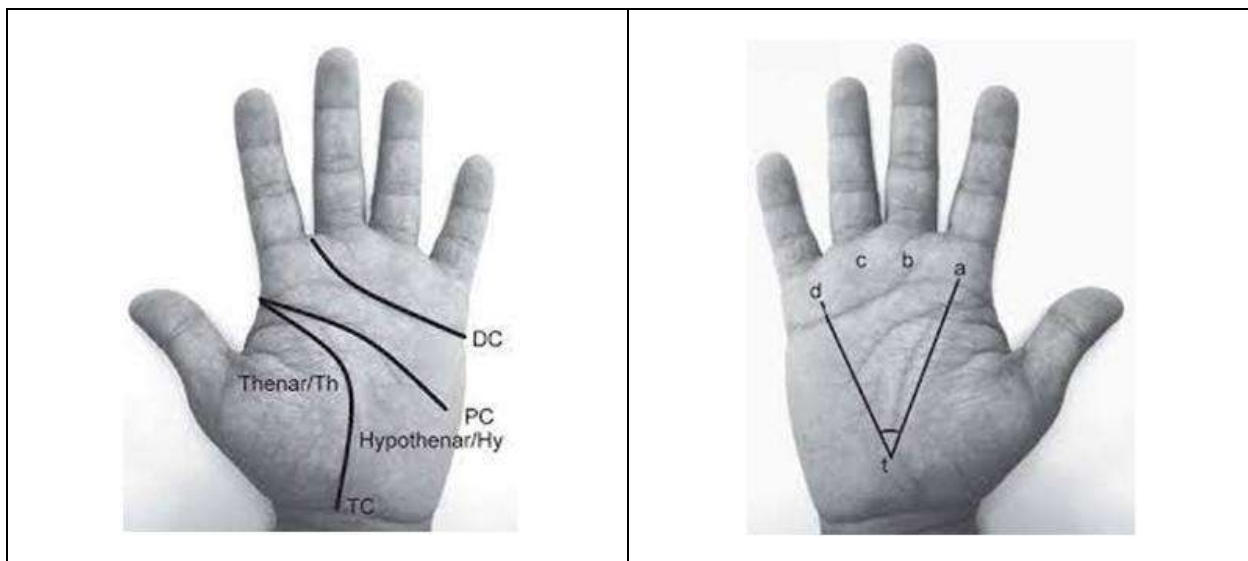


Fig.1:Types of Palmar and Fingertip Patterns

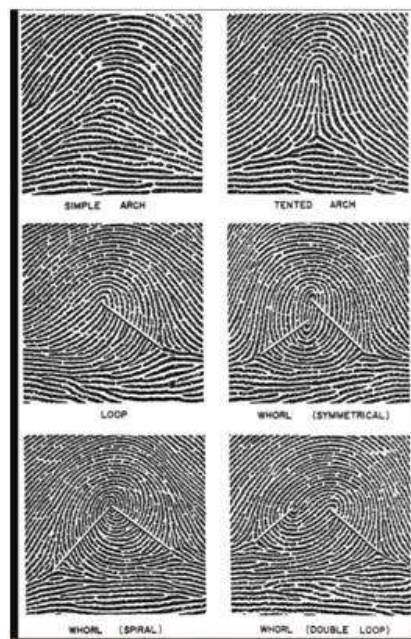
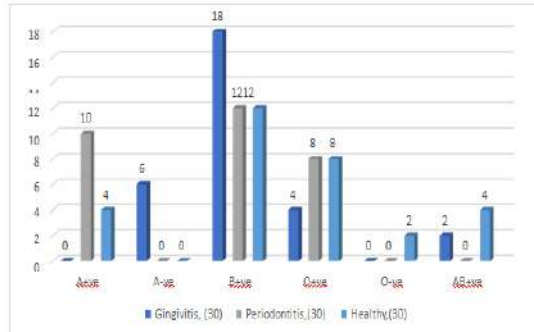
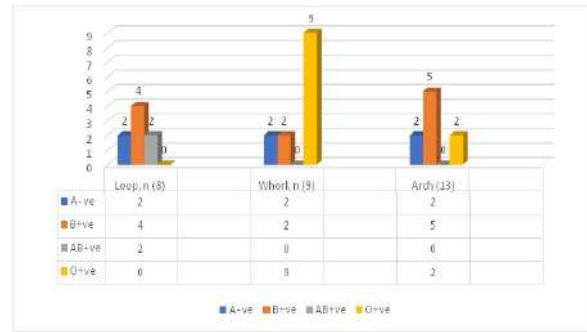


Figure.2: Galton's types of fingerprints and the lines indicating method for counting ridges. (9)

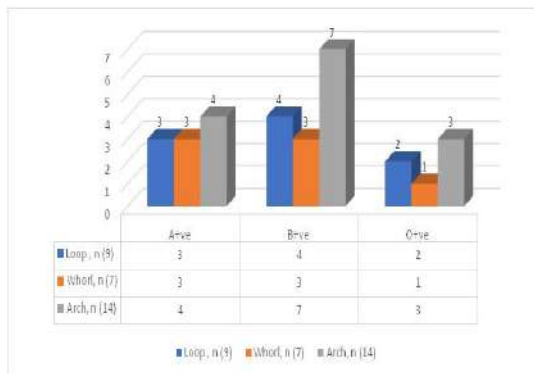




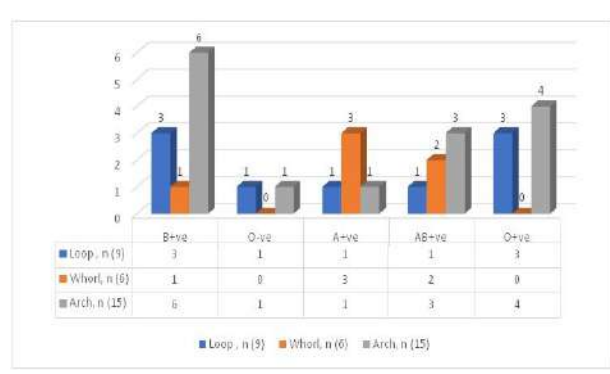
Graph.1 : Comparison between periodontal status and blood groups



Graph.2 : Relationship between gingivitis, Thumbprints and blood groups



Graph.3 : Relationship between periodontitis, thumbprints and Blood groups



Graph.4: Relationship between healthy controls, thumbprints and Blood groups





Benzothiazole Derivative : A Review on its Different Activity

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ABSTRACT

Since benzothiazole derivatives have a wide range of pharmacological activities, there has been a lot of interest in their development and research in recent years. It has been discovered that substances based on benzothiazoles are useful in the treatment of a number of illnesses, such as cancer, bacterial infections, depression, and cardiovascular disorders. There has been a lot of research done on the synthesis of benzothiazole derivatives, and various synthetic techniques have been developed to obtain these compounds. Antitumor, antibiotic, antifungal, antimicrobial, antidepressant, HIV-1 protease inhibitory, and antiarteriosclerosis properties are just a few of the many biological activities demonstrated by benzothiazole derivatives. Research into the pharmacological characteristics of benzothiazole derivatives is still an exciting field with the possibility of finding novel medications and treatments. An extensive summary of the synthesis and biological activities of benzothiazole and its derivatives is given in the current review. It is anticipated that this review will stimulate more study and development of benzothiazole-based compounds with improved pharmacological properties. It will also be a valuable resource for researchers in the fields of synthetic chemistry and drug discovery.

Keywords: Benzothiazole, Pharmacological activities, Heterocyclics.





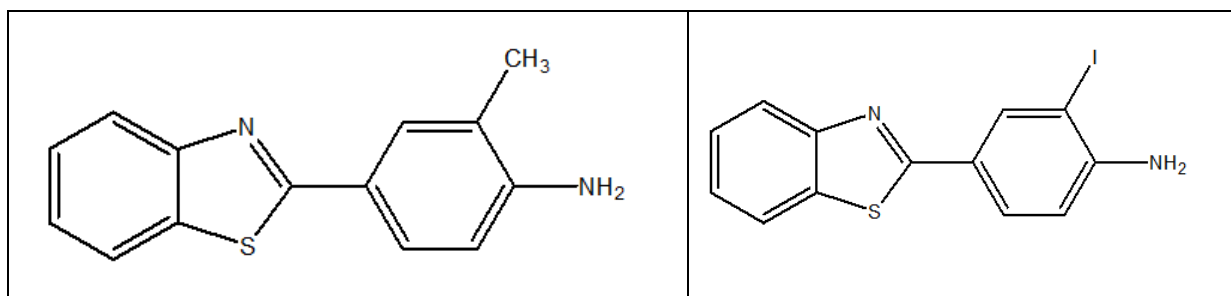
INTRODUCTION

The wide range of physiological functions exhibited by heterocyclic compounds, like benzothiazole, makes them extremely important in organic chemistry and drug discovery.¹ A lot of research has been done on the possible biological activities of benzothiazole and its derivatives. A study on the muscle-relaxing potential of benzothiazole derivatives, specifically 2-aminobenzothiazoles, was conducted in the 1950s. Ever since, a variety of pharmacological actions, such as antibacterial, anti-inflammatory, analgesic, anticonvulsant, antidepressant, antiviral, anthelmintic, antioxidant, and anticancer properties, have been discovered in benzothiazole analogues. Benzothiazole analogues can be made in a number of ways. One popular method is the condensation process, which forms benzothiazole derivatives by reacting acyl chlorides, carboxylic acids, esters, nitriles, and o-aminothiophenols with substituted aldehydes. The cyclization of o-halothioformanilide by Pd/Cu/Mn/chloranil is another common technique. The creation of a wide range of benzothiazole derivatives with various structural variations and pharmacological effects has been made possible by these synthetic techniques. Benzothiazole compounds and their derivatives are still being studied for their potential uses and other characteristics.

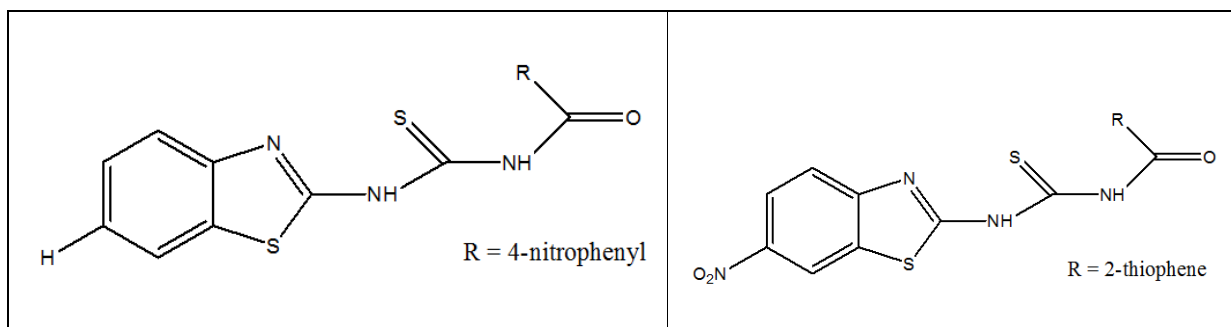
Pharmacological Activities

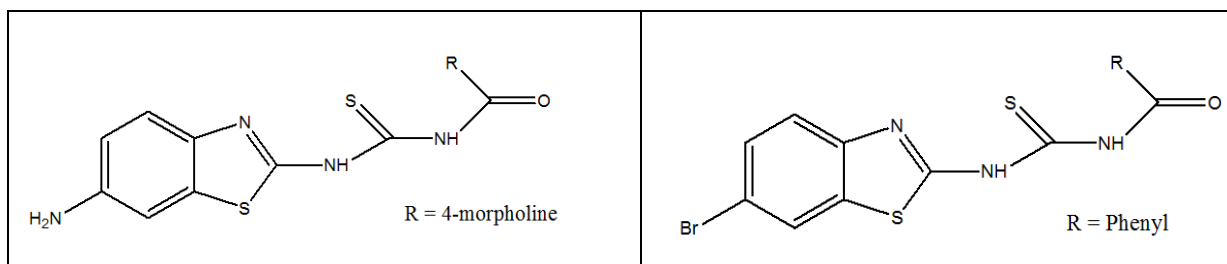
Anticancer activity

To create novel lead compounds for the treatment of different types of cancer, a thorough investigation into the benzothiazole chain systems was carried out.^[1] A variant of 2-(4-aminophenyl) benzothiazole in which alkyl, hydroxy, cyano, and alkoxy groups have been substituted shown to possess anticancer properties in vitro. The compound containing –CH₃ substitution (1.a) exhibited highly effective development restriction or suppression towards cancers classified as ER+ (MCF-7 and BO) and ER- (MT-1 and MT-2).^[2,3]

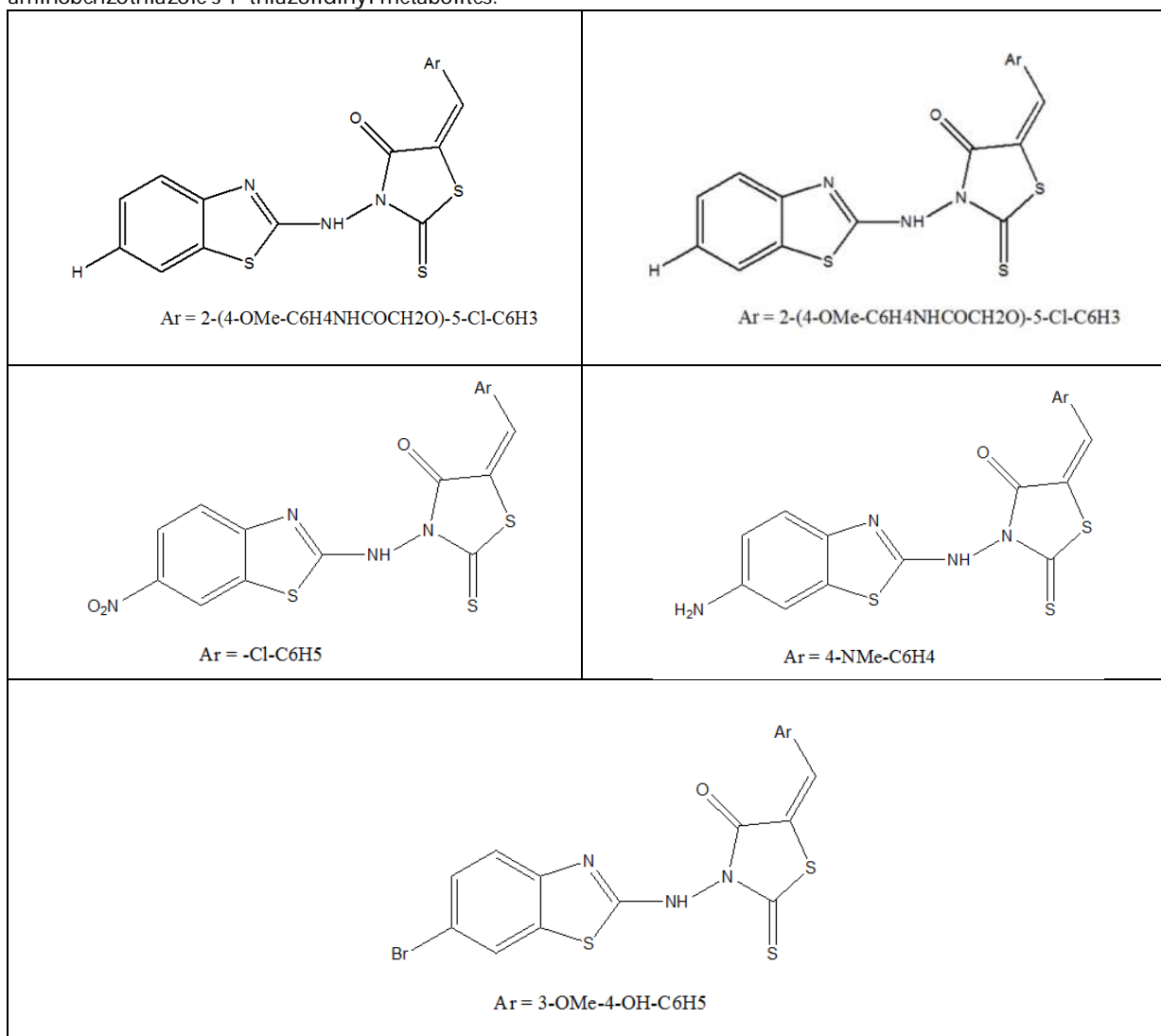


The ability to combat cancer in MCF-7 and HeLa cell lines was discovered after a series of benzothiazole derivatives with a 2-thiourea substitution were synthesized.



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The most effective activity was shown by molecules with derivatives of the thiourea-benzothiazole replaced with thiophene or morpholine, which enhanced apoptosis by activating the caspase-3 signaling. This research was based on studies conducted by two different research groups to investigate benzothiazole's interactions and the thiourea moiety upon the topoisomerases enzyme I and II.^[4] The same group of scientists synthesized the substituted 2-aminobenzothiazole's 4'-thiazolidinyl metabolites.

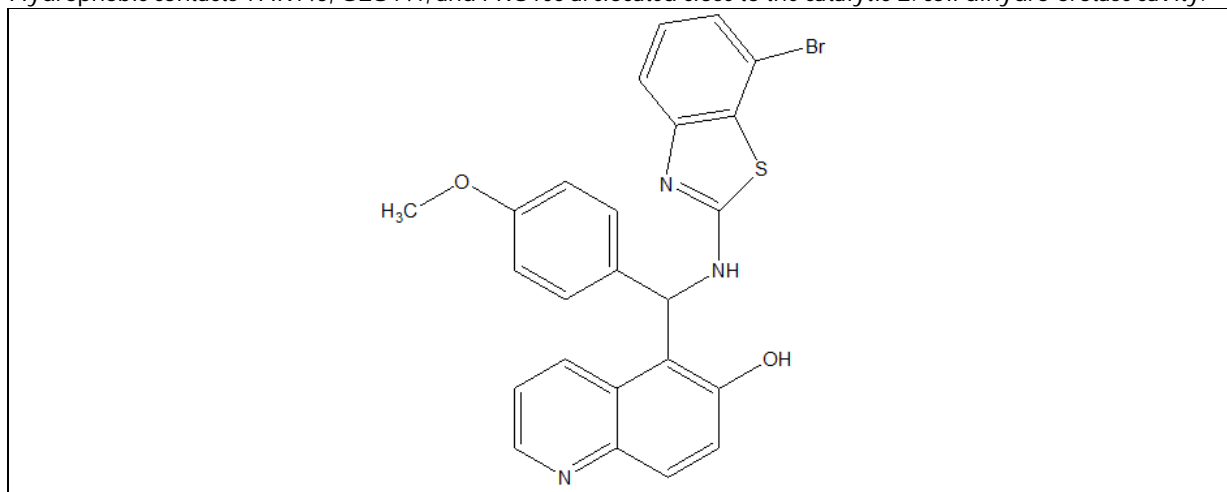


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The moiety of 4-thiazolidinone was the basis for a previous investigation used for this study. [5,6] The antitumor efficaciousness of the synthesized compounds is examined in a number of cancerous cellular lines (tumors of the central nervous system, ovaries, kidney, lungs, colonic, leukemia, and chest tumors). 4-Chlorophenoxy-N-(4-methoxyphenyl)-acetamide demonstrated the most notable action against all of the cell lines.[7] This research revealed the importance of the hybridized design phase for a novel molecule involving benzothiazole derivatives for cancer treatment. "

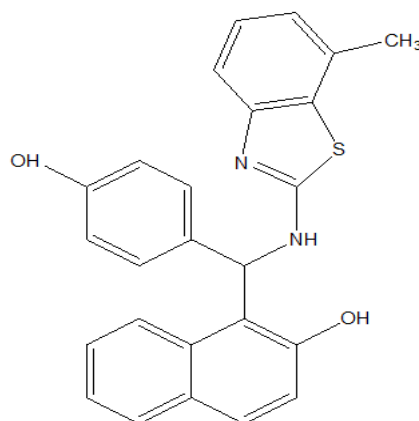
Antibacterial Activity

synthesized, and its antifungal and antibacterial activity against *E. coli*, *S. aureus*, and *B. subtilis* was assessed. [8] It demonstrated antimicrobial properties and mild antifungal properties against *Candida albicans* and *Aspergillus niger*. proved to possess the strongest antimicrobial properties, and as a result, it was followed by additional substances that were very successful against all of the bacterial species that were looked at. The antimicrobial activities of *E. coli* dihydro-orotase were investigated in order to further evaluate the docking data obtained for antibiotic properties. Large H-bonding network formed by the basic ligand HDDP, HIS254, ARG20, ASN44, LEU222, ALA266, and HIS139. One H-bond forms along with the branch chains of LEU222 when the phenol grouping, which is present in the cavity containing HDDP, is introduced. [35] Likewise, resulted in the formation of an H-bond between the oxygen from the methoxy group and the internal chain of ALA266. Furthermore, the naphthalene ring also forms Hydrophobic contacts THR143, GLU141, and PRO105 are located close to the catalytic *E. coli* dihydro-orotase cavity.



It was somewhat effective against the tested strains of bacteria.[9] Not much research has been done on the antibacterial qualities of benzothiazole derivatives against bacteria and fungi that are infectious. Compound 11 methyl-benzothiazole interacts with CYS221, CYS256, and ARG258 branches chains in a significant way. A lower predicted docking score is caused by the loss of H-bonds when hydrogen is joined to the receptor during the few groups that could act as donors or receptors. Moreover, the transition state of the enzyme is impacted by stacking compound 11 with HIS254, which led to a decrease in activity.

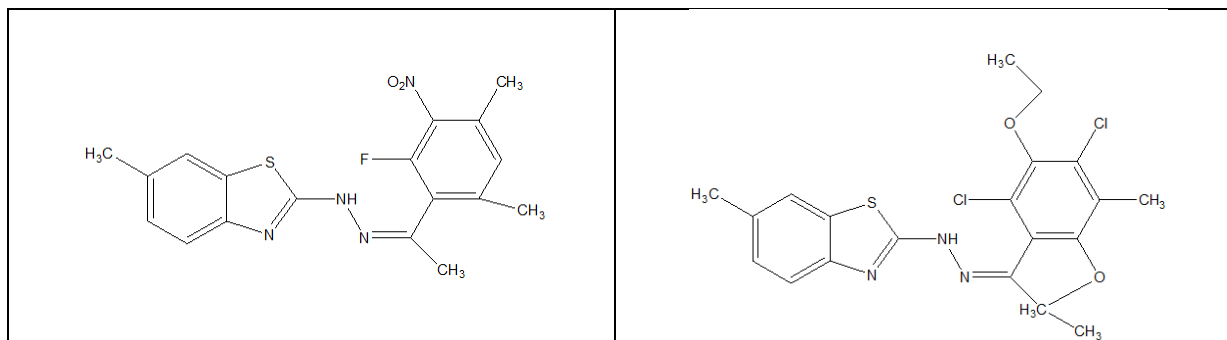


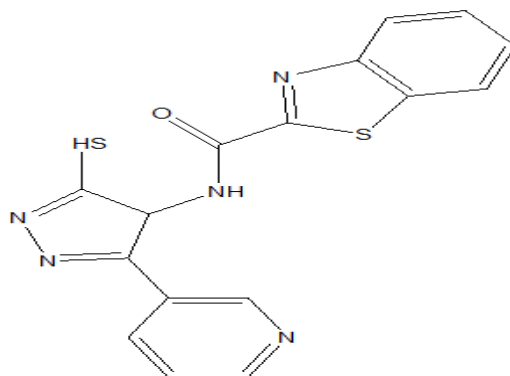
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The benzothiazole-based bactericidal agents were linked to different types of bacteria and act as enzyme inhibitors for essential bacterial cell activities such as DNA replication, cell differentiation, and the synthesis of cell walls or the biogenesis of required compounds.[10] Dihydroorotase inhibition has been the subject of numerous articles examining both Gram-ve and Gram+ bacterial species, demonstrating its utility as a target for the synthesis of antimicrobial medications.[11,12]

Antifungal Activity

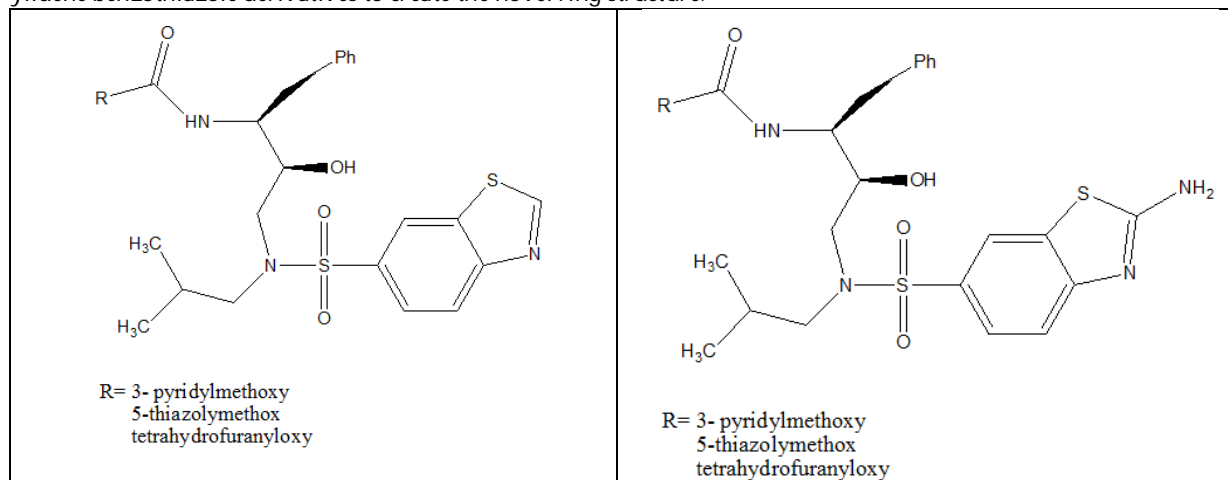
A number of 4-(2'-substituted benzothiazoles and several 2-substituted benzothiazoles 5-mercapto-3-(modified)Analogues of -1,2,4-triazole were prepared and tested for their ability to inhibit *E. coli* and *S. aureus* bacteria as well as *C. albicans* and *A. niger* fungus.[13] For both activities, the majority of drugs showed positive results.





Antiviral Activity

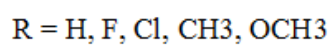
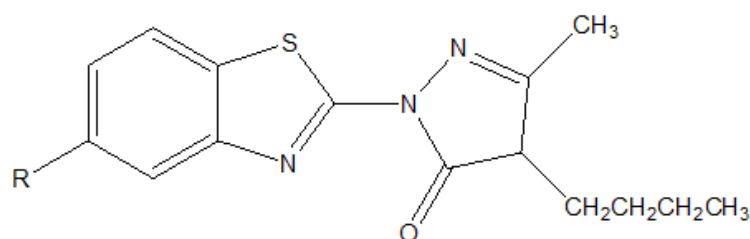
HIV-1 protease was found to be inhibited by novel benzothiazole sulphonamides (compounds 15 and 16), with an IC₅₀ value of 1-3 nM.^[14] More powerful antiviral and HIV-1 protease inhibitors have been demonstrated for the carbamate equivalents. It was determined how effective the newly substituted 2-pyrimidylbenzothiazoles were against viruses by looking at their sulphonamide moiety, which is the amino compound located right at the C2 of the pyrimidine ring. Michael addition was used to combine guanidine or N-arylsulfonated guanidine with a number of yliden benzothiazole derivatives to create the novel ring structure.



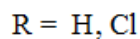
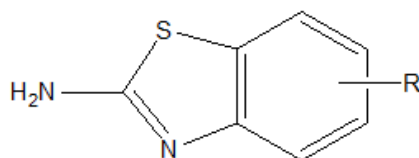
Anti-inflammatory Activity

In order to treat inflammation, several novel benzothiazoles were prepared, including 2-(4'-butyl-3',5'-dimethylpyrazol-1'-yl)with 4-butyl-1-(6'-substituted-2'-benzothiazolyl) benzothiazoles with a 6-substitution. It was discovered that compound, 18 had a strong anti-inflammatory effect [15,16]



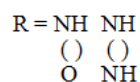
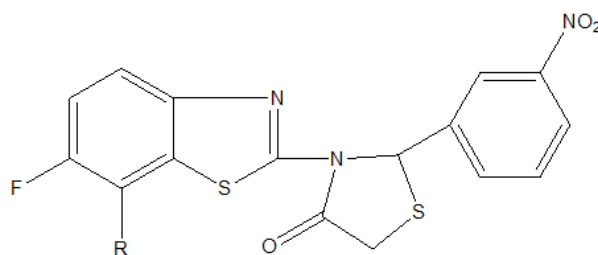


Benzothiazole-based anti-inflammatory medications were created and their potential to lower inflammation was evaluated using a novel 2-amino-benzothiazole derivative. When the 2-amino benzothiazole was substituted at positions 4 or 5 with an electron-withdrawing group, such as -Cl, -NO₂, or -OCH₃, it was found that the anti-inflammatory activity was significantly increased.[17]



Antitubercular Activity

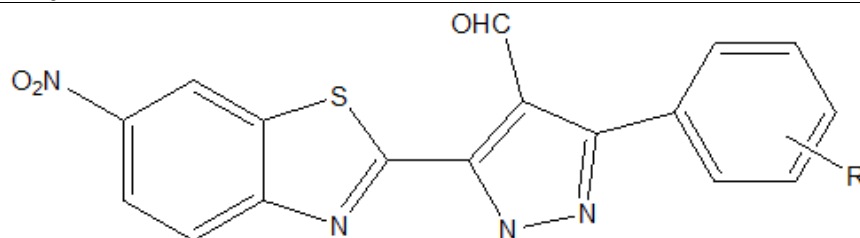
It was found to possess significant *in vitro* antitubercular activity against *Mycobacterium tuberculosis*.





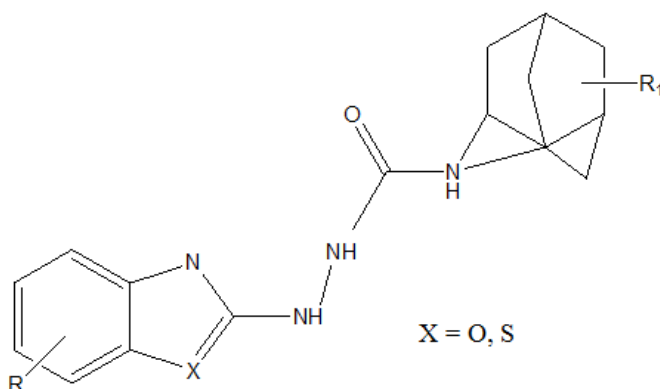
Samiksha Kumbhare et al.,

The antitubercular activity of 6-nitro-2-[4-formyl-3-(phenyl substituted) pyrazolyl] benzothiazoles against the H37RV strain of *Mycobacterium tuberculosis* was synthesized and examined. Benzothiazoles (compound 21) showed the most promising activity in antitubercular screens [18]

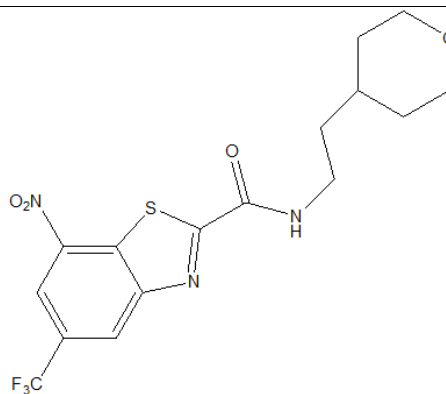
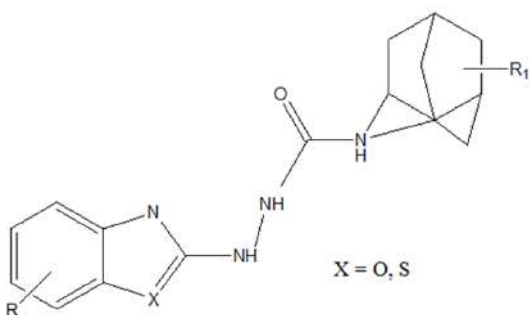


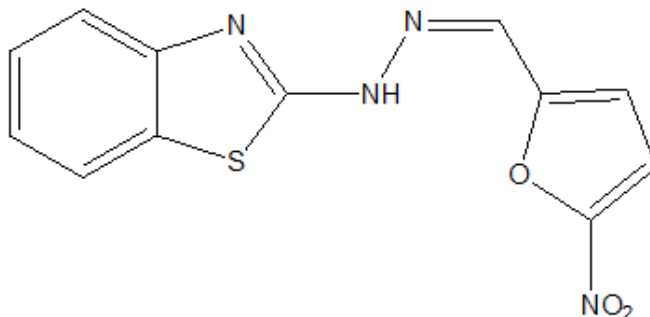
R = H, OH, Br, NO₂, OCH₃, OH, Cl, F, CH₃, di-OCH₃

The antimycobacterial activity of derivatives of adamantanyl benzothiazoles was demonstrated in an updated patent.[19,20] Among these, it was found to be isoniazid-equivalent, with a MIC₉₀ of 0.03 g/ml against H37Rv.

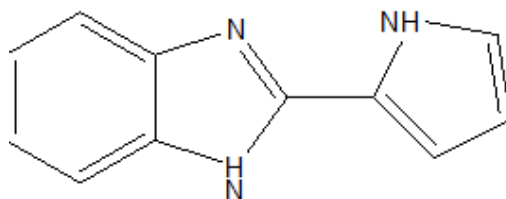


mycobacterium tuberculosis has shown good growth inhibition from the series, with a minimum inhibitory concentration of 224 nM. The MIC for the nitrofuranyl-benzothiazole hydrazones as an antitubercular medication was greater than 16 g/ml.



Samiksha Kumbhare *et al.*,**Anti-oxidant Activity**

A variety of compounds, including benzothiazole analogues and arylbenzimidazoles, including benzofuranhydrazones, benzimidazolidrazones, and indole-hydrazones, were synthesized and tested for their antitumor and antioxidant properties.^[21] Together with favorable photoprotective or antitumor activity profiles, these compounds demonstrated potent antioxidant properties. In particular, they showed an IC₅₀ of 9.7 µM against human melanoma cells, as well as 2 g/ml IC₅₀ levels against the investigated dermatophytes and good in vitro antioxidant activity in DPPH and FRAP tests.

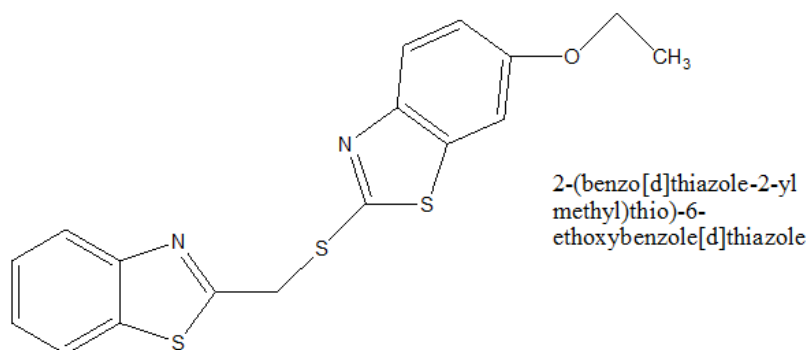


Lead Compound

Antidiabetic Activity

Benzothiazole derivatives have been shown to have antidiabetic properties, and further application of the benzothiazole core may result in the creation of safe antidiabetic medications.^[22] One of the primary targets of the newest anti-diabetic drugs is the enzyme adenosine-5'-monophosphate activated protein kinase (AMPK). 2-(hydroxy-5-((Z)-((E)-((4,5-dimethyl-2-nitrophenyl)furan-2-yl)methylene)AMPK enzyme auto-inhibition is reduced by PT-1 (-4-oxothiazolidin-2-ylidene)benzoic acid. Several benzothiazoles with comparable structures made it easier for L6 myocytes to absorb glucose using an AMPK-dependent method. High glucose absorption speed was demonstrated by 2-(Benzo[d]thiazol-2-ylmethylthio)-6-ethoxybenzo[d]thiazol.^[23]





CONCLUSION

The variety of biological functions and synthetic routes of benzothiazoles are highlighted in the recent literature. Many biological activities are displayed by the benzothiazole core, such as antibacterial, anticancer, anti-inflammatory, antidepressant, and antidiabetic effects. Because of their inherent range of activities, benzothiazole derivatives have emerged as a promising field for the discovery of new lead molecules. The discovery of the aldose reductase inhibitor Zopolrestat has made it possible to investigate the potential medical uses of benzothiazoles. Certain benzothiazole derivatives have demonstrated activity that is either on par with or better than current standard drugs, suggesting that they have promise as therapeutic agents. This implies that products derived from benzothiazoles may be the basis of soon-to-be-marketed treatments.

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Conflict of Interest

The authors declare that they do not have conflict of interest.

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Exploring Antioxidant Potential of Bavana Kadukkai Mathirai: An *In-vitro* Analysis

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ABSTRACT

A traditional Siddha herbo-mineral formulation called Bavana Kadukkai Mathirai (BVK) is thought to provide a host of health advantages, such as rejuvenation and disease prevention. This study uses *in-vitro* assays to assess BVK's antioxidant capacity. To evaluate BVK's capacity to scavenge free radicals, we used four distinct assays: DPPH, ABTS, Nitric Oxide, and Hydrogen Peroxide Radical Scavenging. The findings showed that antioxidant activity increased in all experiments in a dose-dependent manner. With 93.08% inhibition at 1 mg, BVK showed significant antioxidant activity in the DPPH assay, on par with common antioxidants as Trolox and ascorbic acid. Moderate antioxidant effects were found in the ABTS, Nitric Oxide, and Hydrogen Peroxide assays; at the maximum dose, BVK showed inhibition values of 78.09%, 31.91%, and 49.48%, respectively. These findings suggest that BVK has a lot of antioxidant potential, particularly in eliminating DPPH radicals, making it a viable natural antioxidant source. More research is required to learn more about its methods of action and possible therapeutic uses.

Keywords: Siddha medicine, Bavanakadukkai, Kayakarpam, Antioxidant, Internal Medicine.





INTRODUCTION

The Siddha medical system, which is well known in Southern India, offers a distinctive method of approaching health care by providing a comprehensive range of treatments and cures that are outlined throughout Siddha literature for a variety of disorders. Kayakarpam is one of these, and it is an important medication that tries to either increase longevity or avoid mortality. In Siddha terminology, the word "Kaya" refers to the body, and the word "Karpam" suggests a strength that is comparable to that of a stone. The Siddhar sage Thirumoolar, who believed that rejuvenation was a step towards salvation, underlined the fact that this therapy places an emphasis on rejuvenation and that it advocates for the purification of the soul through the preservation of the body. In the Siddha literature, 4,448 different disorders are discussed. These diseases treated using 32 different internal and 32 different external medicinal categories. Kayakarpam is a notable component of this system. In Siddha literature, particularly the Siddha Formulary of India, Part 1, the formulation known as Bavana Kadukkai is noted for its possible anti-aging and health advantages. This formulation is considered to be one of the notable Kayakarpam formulations. (1-2) Antioxidants are substances that protect cells from oxidative damage by neutralizing damaging free radicals. (3) As a result, they reduce the chance of developing chronic diseases. Because of their ability to scavenge free radicals at the biochemical level, these chemicals, which include vitamins C and E, beta-carotene, and polyphenols, play an important part in rejuvenating therapies. They contribute to the preservation of cellular health and delay the consequences of aging. (4-6) Biological free radicals are highly unstable molecules that have electrons available to react with various organic substrates such as lipids, proteins, and DNA might hasten the aging process and contribute to the development of chronic diseases. (7-8) The body possesses its antioxidant defenses, which consist of enzymes like glutathione peroxidase, catalase, and superoxide dismutase, among others. (9-10) On the other hand, environmental contaminants and lifestyle variables have the potential to overwhelm these systems, highlighting the significance of dietary antioxidants in the maintenance of cellular health and the support of the rejuvenative processes of the body, as Siddha medicine emphasizes. (11-13) This research was conducted to determine the antioxidant capacity of *Bavana Kadukkai Mathirai* by employing an in-vitro model and conducting several different assays.

MATERIALS AND METHODS

Collection and Authentication of Raw Drugs

The raw materials for Bavana Kadukkai were sourced from "Rajendra herbals in Thakkalai, Kanyakumari, Tamil Nadu, India" and were authenticated by a medicinal botanist and the Gunapadam faculty at the "National Institute of Siddha, Chennai."

Ingredients of *Bavanakadukkai Mathirai*

The ingredients of *Bavanakadukkai Mathirai*, as noted in Table 1

Purification

We weighed and purified the raw drug by removing sand, dust particles, small sticks, and other impurities (14-15).

Preparation of *Bavana Kadukkai*

Kadukkai was soaked in *kazhuneer* for three days, and this process was repeated twice with fresh *kazhuneer* over nine days. After soaking, the *Kadukkai* was washed with water, and the seeds were removed. The purified *Kadukkai* was allowed to dry. *Kadaluppu*, *Mor*, and the purified *Kadukkai* were placed in a mud pot and boiled until all the water evaporated. Nos. 5 to 11 ingredients were ground into a fine powder and mixed with the *Kadukkai* mixture. Lemon juice was added, and the mixture was left in sunlight to dry completely. This process was repeated with ginger juice until the *Kadukkai* reached the desired consistency, after which it was shaped into pills and stored in an airtight container.



Manivannan *et al.*,**Dosage**

1-2 pills, before food, 40 days.

Indication

Irumal (Cough), *Mantham* (Indigestion), *Vayittru noi* (Stomach pain) and *Vanthi* (Vomiting). Taking this medicine for 40 days will cure the following conditions: *Soolai* (Throbbing pain), *Vaayu*, *Gunmam* (Ulcer), *Moolam* (Hemorrhoids), *Iraippu* (Bronchial asthma), *Peelikam* (Splenomegaly), *Peenisam* (Sinusitis), *Veluppu noi* (Anaemia), *Suvai inami* (Ageusia), and *Oon veruppu* (Anorexia).

In Vitro Antioxidant Activity**Free radical scavenging ability by the use of a stable DPPH radical (1,1-diphenyl-2-picrilhydrazyl)**

The effect of given samples on DPPH radical was estimated according to the procedure described by Von Gadow *et al.* (1997). Two ml of a 6×10^{-5} M methanolic solution of DPPH were added to 50 μ L of the sample solution with different concentrations (2 μ L extract + 48 μ L water, 4 μ L extract + 46 μ L water, 6 μ L extract + 44 μ L water, 8 μ L extract + 42 μ L water, and 10 μ L extract + 40 μ L water). The decrease of absorbance at 515 nm was recorded in a spectrophotometer for 16 min at room temperature. The scavenging effect (decrease of absorbance at 515 nm) was plotted against the time and the percentage of DPPH radical scavenging ability of the sample was calculated from the absorbance value at the end of 16 min in duration as follows:

All determinations were performed in triplicate. The percentage inhibition of the DPPH radical by the samples was calculated according to the formula of Yen and Duh (1994).

$$IP = [(AC(0) - AA(t)) / AC(0)] \times 100$$

Where AC(0) is the absorbance of the control at t = 0 min, and AA(t) is the absorbance of the antioxidants at t = 16 min (16-18).

Free radical scavenging ability by the use of a stable ABTS radical cation 2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)

The ABTS radical cation decolorization assay (Re *et al.*, 1999) tested the free radical scavenging capacity of samples. ABTS was dissolved in water to get a 7 mM concentration. ABTS radical cation (ABTS^{•+}) was produced by reacting ABTS stock solution with 2.45 mM potassium persulphate (final concentration) and allowing the mixture to stand in the dark room temperature for 12-16 hrs before use. The free radical was stable for more than two days when stored in the dark room temperature. For the study of the test samples, the ABTS^{•+} solution was diluted with absolute ethanol to an absorbance of 0.700 (± 0.02) at 734 nm and equilibrated at 30°C. Reagent blank reading was taken (A₀). After the addition of 2.0 mL of diluted ABTS^{•+} solution (A_{734 nm} = 0.700 (± 0.02)) to 50 μ L of the test sample (20 mg/mL), the absorbance reading was taken at 30°C exactly 6 min after initial mixing (A_t). Appropriate solvent blanks were run in each assay. All determinations were carried out at least three times. The percentage inhibition of absorbance at 734 nm was calculated using the above formula and the decrease of the absorbance between A₀ and A_t.

$$PI = [(AC(0) - AA(t)) / AC(0)] \times 100$$

Where AC(0) is the absorbance of the control at t = 0 min; and AA(t) is the absorbance of the antioxidant at t = 6 min (19-21).

Hydrogen peroxide scavenging activity

The scavenging activity of hydrogen peroxide by the plant extract was estimated using the method of Ruch *et al.* (1989). Plant extract (4 ml) prepared in distilled water at various concentrations was mixed with 0.6 ml of 4 mM H₂O₂ solution prepared in phosphate buffer (0.1 M pH 7.4) and incubated for 10 min. The absorbance of the solution was taken at 230 nm against a blank solution containing the plant extract without H₂O₂. The reaction mix containing H₂O₂ radical without plant extract served as a control. The amount of hydrogen peroxide radical inhibited by the extract was calculated using the following equation:

$$H_2O_2 \text{ radical scavenging activity} = \{(Abs \text{ control} - Abs \text{ sample}) / (Abs \text{ control})\} \times 100$$



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Where; Abs control is the absorbance of H₂O₂ radical; Abs sample is the absorbance of H₂O₂ radical + sample extract (22-24).

Nitric oxide scavenging activity

Nitric oxide generated from sodium nitroprusside in an aqueous solution at physiological pH was measured by the Griess reaction (Marcocci et al., 1994). The reaction mixture (3ml) containing sodium nitroprusside (10mm) in phosphate buffer saline and the test extract (10, 25, 50 and 100µg/ml) was incubated at 25°C for 150min after incubation 1.5ml of the reaction mixture was removed and 1.5ml of the Griess reagent (1% sulphanilamide, 2% orthophosphoric acid and 0.1% Naphthylmethyl diamine hydrochloride) was added. The absorbance of the chromophore formed was read at 546 nm. Percent inhibition of nitric oxide scavenging was calculated using the formula. Percentage Inhibition = (A of Control – A of Sample) / A of Control × 100. A- absorbance (25-26).

RESULT AND DISCUSSION

The antioxidant potential of the test drug BVK was evaluated using four different assays: DPPH, ABTS, Nitric oxide, and hydrogen Peroxide radical scavenging assays. The results were compared with standard antioxidants.

DPPH Assay

The DPPH radical scavenging assay results for BVK demonstrate a clear, concentration-dependent increase in antioxidant activity. The control sample showed an optical density (OD) of 0.621, corresponding to 0% inhibition. At 0.2 mg, the OD was reduced to 0.126, yielding 79.71% inhibition, and at 0.4 mg, the OD further decreased to 0.07, resulting in 88.73% inhibition. At 0.6 mg, the OD dropped to 0.061, with 90.18% inhibition, and at 0.8 mg and 1 mg, the ODs were 0.052 and 0.043, respectively, with inhibitions of 91.63% and 93.08%. These results indicate that BVK exhibits a significant dose-dependent increase in antioxidant activity, with the highest inhibition (93.08%) observed at 1 mg. When compared to well-established antioxidants like ascorbic acid and Trolox, BVK's performance is highly promising. Ascorbic acid, a well-known antioxidant, typically achieves DPPH inhibition in the range of 90-95% at similar concentrations, while Trolox, a synthetic analogue of vitamin E, generally demonstrates 85-95% inhibition. BVK's inhibition values, consistently close to or exceeding 90%, suggest that its antioxidant efficacy is comparable to or even superior to that of ascorbic acid and Trolox at equivalent concentrations. Additionally, BVK exhibited a significant antioxidant effect with an IC₅₀ value of 0.25 mg, which is comparable to ascorbic acid (IC₅₀ = 0.22 mg) and Trolox (IC₅₀ = 0.28 mg). The maximum inhibition of 93.08% at 1 mg was similar to ascorbic acid's 95.12% at the same concentration. The findings highlight that BVK could be a competitive antioxidant, offering free radical scavenging capabilities on par with or surpassing those of established standards like ascorbic acid and Trolox.

ABTS Assay

The ABTS radical cation Decolorization assay results for the test sample reveal a clear, dose-dependent increase in antioxidant activity with rising concentrations. The control sample showed an optical density (OD) of 0.703, corresponding to 0% inhibition. At 0.2 mg, the OD decreased to 0.501, resulting in 28.73% inhibition, while at 0.4 mg, the OD further decreased to 0.258, yielding 63.30% inhibition. At 0.6 mg, the OD was reduced to 0.201, producing 71.41% inhibition, and at 0.8 mg and 1 mg, the ODs were 0.189 and 0.154, leading to inhibitions of 73.12% and 78.09%, respectively. These results suggest a significant increase in antioxidant activity as the concentration of the sample rises. When compared to well-established antioxidants like ascorbic acid and Trolox, BVK's performance is notable. Ascorbic acid typically demonstrates ABTS radical scavenging activity in the range of 80-95%, with its efficacy improving at higher concentrations. Trolox, a synthetic analogue of vitamin E, shows similar strong ABTS scavenging activity, typically ranging from 75-90%, with its activity also increasing with concentration. BVK's maximum inhibition of 78.09% at 1 mg, while slightly lower than the performance of ascorbic acid (90-95%) and Trolox (85-90%), still indicates significant antioxidant potential. BVK exhibited moderate antioxidant activity, with an IC₅₀ value of 0.43 mg, which is slightly higher than that of ascorbic acid (IC₅₀ = 0.35 mg) and Trolox (IC₅₀ = 0.38 mg). The maximum inhibition of 78.09% at 1 mg was lower than ascorbic acid's 85.61% at the same concentration.



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Although BVK's antioxidant activity appears slightly less potent than that of ascorbic acid and Trolox at equivalent concentrations, it remains a competitive antioxidant. These findings suggest that BVK holds promise as an effective free radical scavenger.

Nitric Oxide Assay

The nitric oxide (NO) scavenging assay results for the test sample demonstrate a dose-dependent increase in antioxidant activity with rising concentrations. The control sample had an optical density (OD) of 0.987, corresponding to 0% inhibition. At 0.2 mg, the OD decreased to 0.874, leading to 11.45% inhibition, and at 0.4 mg, the OD further decreased to 0.801, yielding 18.84% inhibition. At 0.6 mg, the OD dropped to 0.754, resulting in 23.61% inhibition, and at 0.8 mg and 1 mg, the ODs were 0.716 and 0.672, corresponding to 27.46% and 31.91% inhibition, respectively. These results indicate that the sample's ability to scavenge nitric oxide increases with concentration, with the highest inhibition of 31.91% observed at 1 mg. Although BVK demonstrated moderate antioxidant activity, with a maximum inhibition of 31.91% at 1 mg, its effectiveness was significantly lower compared to well-known antioxidants like ascorbic acid (85.61% inhibition at 1 mg) and Trolox (78.52% inhibition at 1 mg). This suggests that while BVK shows some capacity to scavenge nitric oxide, its potency is relatively weak compared to ascorbic acid and Trolox. It looks like BVK might work as an NO scavenger because the inhibition increases with higher concentrations. But more research is needed, and comparisons with other known NO scavengers are needed to fully understand how well it works.

Hydrogen Peroxide Assay

The hydrogen peroxide (H₂O₂) radical scavenging assay results for the test sample reveal a dose-dependent increase in antioxidant activity with rising concentrations. The control sample had an optical density (OD) of 0.097, corresponding to 0% inhibition. At 0.2 mg, the OD decreased to 0.078, resulting in 19.59% inhibition, and at 0.4 mg, the OD further decreased to 0.064, yielding 34.02% inhibition. At 0.6 mg, the OD dropped to 0.058, resulting in 40.21% inhibition. At 0.8 mg and 1 mg, the ODs were 0.054 and 0.049, corresponding to 44.33% and 49.48% inhibition, respectively. BVK exhibited moderate antioxidant activity, with a maximum inhibition of 49.48% at 1 mg, comparable to ascorbic acid (52.13% at 1 mg) and Trolox (50.21% at 1 mg). These results demonstrate that BVK's ability to scavenge hydrogen peroxide increases with concentration, reaching the highest inhibition of 49.48% at 1 mg. This indicates that BVK possesses moderate antioxidant activity in terms of hydrogen peroxide scavenging, with inhibition improving as the concentration increases. While BVK's performance is comparable to that of ascorbic acid and Trolox at 1 mg, further studies are necessary to assess its full potential relative to these well-established antioxidants. These findings suggest that BVK shows promise as a hydrogen peroxide scavenger, but additional investigation, particularly with a broader concentration range, would provide a clearer picture of its comparative efficacy. Although BVK's antioxidant activity was lower than that of standard antioxidants, its potential is notable, especially considering that it is a mixture of raw drugs, whereas ascorbic acid is a single, isolated compound.

CONCLUSION

The study highlights the antioxidant potential of the test drug BVK, revealing significant activity in the DPPH assay and moderate activity in the ABTS and hydrogen peroxide assays. However, its limited activity in the Nitric Oxide assay suggests that BVK may not be effective against all types of free radicals. Compared to standard antioxidants, BVK showed similar antioxidant activity in DPPH and hydrogen peroxide assays but lower activity in ABTS and nitric oxide assays. Further studies are necessary to elucidate the mechanisms of action and potential applications of BVK as an antioxidant agent.





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Author contribution

Conceptualization: MV; Data collection and compilation: MV & SR; Manuscript Writing: MV, SR, ML, & KG; Proofreading and editing: MV, SR, ML & NJMK.

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Table.1: Ingredients of Bavanakadukkai Mathirai

S.No	Name of the Ingredient	Scientific name/English name	Quantity
1	Kadukkai	<i>Terminalia chebula</i> Retz.	750 grams
2	Kazhuneer	Rice rinsed water	Sufficient Quantity
3	Mor	Buttermilk	1400 ml
4	Kadaluppu	Common salt	190 grams
5	Chukku	<i>Zingiber officinale</i> Roscoe	18 grams
6	Attuppu	Salt	18 grams
7	Inthuppu	Rock salt	18 grams
8	Omam	<i>Trachyspermum ammi</i> L.	18 grams



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9	<i>Chevviyam</i>	Root of <i>Piper nigrum</i> L.	18 grams
10	<i>Chithiramoola verpattai</i>	<i>Plumbago zeylanica</i> L.	18 grams
11	<i>Thippili</i>	<i>Piper longum</i> L.	18 grams
12	<i>Elumichampazha saaru</i>	Juice of <i>Citrus limon</i> L.	600 ml
13	<i>Injisaaru</i>	Juice of <i>Zingiber officinale</i>	400 ml

Table.2: Percentage inhibition of test drug BVK on DPPH radical scavenging assay

S. No.	Sample Concentration (mg)	METHOD	Optical Density	RESULTS (%inhibition)
1	Control	DPPH Assay Von Gadow <i>et al.</i> (1997)	0.621	0.00
2	0.2 mg		0.126	79.71
3	0.4 mg		0.07	88.73
4	0.6 mg		0.061	90.18
5	0.8 mg		0.052	91.63
6	1 mg		0.043	93.08

Table.3: Percentage inhibition of test drug BVK on ABTS radical scavenging assay

S. No	Sample Concentration (mg)	METHOD	Optical Density	RESULTS (%inhibition)
1	Control	ABTS radical cation decolorization assay(Re <i>et al.</i> , 1999)	0.703	0.00
2	0.2 mg		0.501	28.73
3	0.4 mg		0.258	63.30
4	0.6 mg		0.201	71.41
5	0.8 mg		0.189	73.12
6	1 mg		0.154	78.09

Table.4: Percentage inhibition of test drug BVK on NO assay

S. No.	Sample Concentration (mg)	METHOD	Optical Density	RESULTS (%inhibition)
1	Control	NO assayMarcocci <i>et al.</i> (1994)	0.987	0.00
2	0.2 mg		0.874	11.45
3	0.4 mg		0.801	18.84
4	0.6 mg		0.754	23.61
5	0.8 mg		0.716	27.46
6	1 mg		0.672	31.91

Table.5: Percentage inhibition of test drug BVK on H₂O₂ assay

S. No.	Sample Concentration (mg)	Method	Optical Density	RESULTS (% inhibition)
1	Control	H ₂ O ₂ radical inhibition assay(Elizabeth and Rao,1990)	0.097	0.00
2	0.2 mg		0.078	19.59
3	0.4 mg		0.064	34.02
4	0.6 mg		0.058	40.21
5	0.8 mg		0.054	44.33
6	1 mg		0.049	49.48



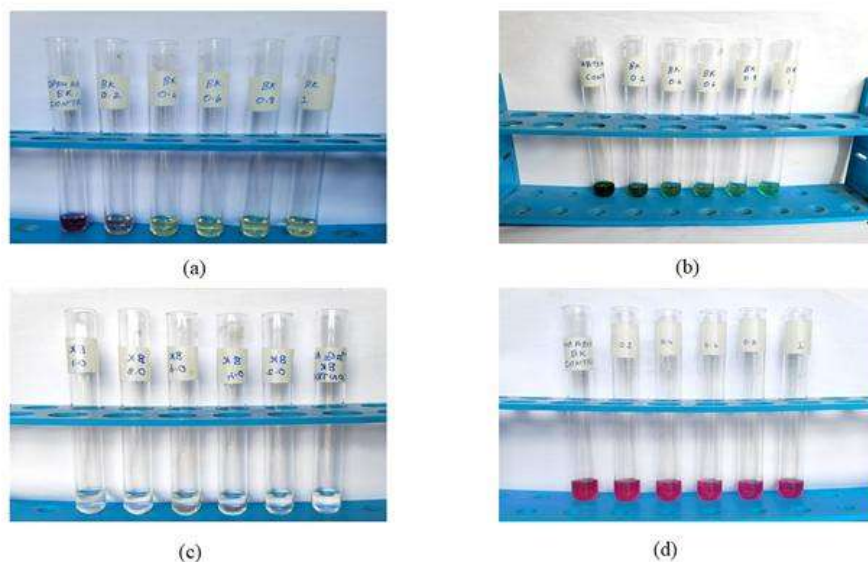


Figure.1: Various assays of BVK demonstrating its antioxidant activity (a) DPPH assay, (b) ABTS assay, (c) NO assay, (d) H₂O₂ assay





Inverses of k - Regular Interval Incline Matrices

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ABSTRACT

We discussed the inverses of k -regular interval incline matrices as a generalization of k -regulars fuzzy matrices and regular (interval) incline. We obtain some properties of k -{3}, k -{4} and k -{3,4} regarding inverses of interval incline matrices (IIM).

Key words: Incline, inverses of k -regular, Fuzzy matrices

2020 Mathematical science Classification : 16Y60, 15B15

INTRODUCTION

Inclines are additively idempotent semirings in which products are less than or equal to either factor. An incline is a structure which has an associative, commutative addition and distributive multiplication Such that $x+x=x$, $x+xy=x$ and $y+xy=y$ for all $x, y \in L$. It has a semiring structure and partial order structure. An element a in an incline is said to be regular if a solution exists for the equation $axa=a$, and such a solution is called a generalized inverse (or g-inverse) of a . An incline L is regular if and only if every element of L is regular. Recently, Meenakshi and Anbalagan examined the regularity of incline elements [11] by using the incline axioms. A matrix $A \in L_{mn}$, (the set of $m \times n$ matrices over an incline L) is regular if and only if there exists $X \in L_{nm}$ such that $AXA=A$, and Such X is called a g-inverse of A . The concept of IVFM is introduced and developed by Shyamal and pal [9]. In [6] Meenakshi and Kaliraja have Studied the regular condition of IVFM. In [10] Meenakshi and Shakila banu have developed on regularity of incline matrices.





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Our previous work [13] we have introduced IIM as a generalization of incline matrices and deals the g-inverse of IIM. Meenakshi and Poongodi [8] introduced the concept of k-regular interval valued fuzzy matrices and discussed the inverses associated with k-regular IVFM. A matrix $T (= [T_L, T_U]) \in L_n^I$, (the set of $n \times n$ interval incline matrices) is said to be right (left) k-regular if there exists $[X_L, X_U]([Y_L, Y_U]) \in L_n$, Such that $[T_L^k X_L T_L, T_U^k X_U T_U] = [T_L^k, T_U^k]$ ($[T_L Y_L T_L^k, T_U Y_U T_U^k] = [T_L^k, T_U^k]$), $[X_L, X_U]([Y_L, Y_U])$ is called a right (left) k-g inverse of $[T_L, T_U]$ where k is a positive integer $k > 1$. we have to development the concept of k-regularity of fuzzy matrices to the IVFM and the Corresponding inverses of k-regular interval incline matrices. In this paper we examined the k-regular interval incline matrices. We obtained some results regarding 1, 3, 4 - k-g- inverses of interval incline matrices. we deal with interval incline matrices (IIM) that is, matrices whose entries are intervals

PRELIMINARIES

In this section, some basic definitions and results needed are given.

Definition 2.1

The interval incline L^I is said to be commutative, if

$$[x_L y_L, x_U y_U] = [y_L x_L, y_U x_U], \quad \forall [x_L, x_U], [y_L, y_U] \in L^I$$

Definition 2.2

(L^I, \leq) is an interval incline with order relation " \leq " defined on L such that for $[x_L, x_U], [y_L, y_U] \in L^I$, $[x_L, x_U] \leq [y_L, y_U]$ if and only if $[x_L + y_L, x_U + y_U] = [y_L, y_U]$ if $[x_L, x_U] \leq [y_L, y_U]$ then y_L is said to dominate x_L (or) y_U is said to dominate x_U

Property 2.1

Interval incline L^I with order relation " \leq ", for

$$[x_L, x_U], [y_L, y_U] \in L^I, [x_L y_L, x_U y_U] \leq [x_L, x_U] \text{ and } [x_L y_L, x_U y_U] \leq [y_L, y_U]$$

Property 2.2

Interval incline L^I with order relation " \leq ", for

$$[x_L, x_U], [y_L, y_U] \in L^I, [x_L + y_L, x_U + y_U] \geq [x_L, x_U] \text{ and } [x_L + y_L, x_U + y_U] \geq [y_L, y_U]$$

Throughout this paper L^I denote the interval incline

Definition 2.3

An (interval) incline is a non empty Set L^I with binary operations addition and multiplication denoted by $(+, \cdot)$ and Satisfying the following (we usually dot \cdot for multiplications) for $a, b, c \in L^I$

- (i) $[a_L, a_U] + [b_L, b_U] = [b_L, b_U] + [a_L, a_U]$;
- (ii) $[a_L, a_U] + ([b_L, b_U] + [c_L, c_U]) = ([a_L, a_U] + [b_L, b_U]) + [c_L, c_U]$;
- (iii) $[a_L, a_U]([b_L, b_U] + [c_L, c_U]) = [a_L, a_U][b_L, b_U] + [a_L, a_U][c_L, c_U]$;
- (iv) $[a_L, a_U]([b_L, b_U][c_L, c_U]) = ([a_L, a_U][b_L, b_U])[c_L, c_U]$;
- (v) $([b_L, b_U] + [c_L, c_U])[a_L, a_U] = [b_L, b_U][a_L, a_U] + [c_L, c_U][a_L, a_U]$;
- (vi) $[a_L, a_U] + [a_L, a_U] = [a_L, a_U]$;
- (vii) $[a_L, a_U] + [a_L c_L, a_U c_U] = [a_L, a_U]$;
- (viii) $[c_L, c_U] + [a_L c_L, a_U c_U] = [c_L, c_U]$;

In an interval incline $(L^I, +, \cdot)$ acting a relation ' \leq ' described as on L^I .





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Definition 2.4

For any interval incline matrices $A = [a_{ijL}, a_{ijU}]$ and $B = [b_{ijL}, b_{ijU}]$ in L_{mn} such that $A \leq B$ the Interval incline matrix $([A_L, A_U], [B_L, B_U]) = ([a_{ijL}, a_{ijU}], [b_{ijL}, b_{ijU}])$ is a Structure that ij^{th} entries is the limit incline with minimum threshold $[a_{ijL}, a_{ijU}]$ and maximum threshold $[b_{ijL}, b_{ijU}]$. In Specific for $A=B$, Interval incline matrix (IIM) $[A_L, A_U]$ is Simplified to the interval incline matrix A^{TM}_{Lmn} . For $A = [A_L, A_U] = [a_{ijL}, a_{ijU}]^{TM(IIM)_{m \times n}}$, clearly the interval incline matrix a_{ijL} and a_{ijU} $^{TM}_{Lmn}$ Such that $a_{ijL} \leq a_{ijU}$. Consequently, by these means Definition (2.4) A matrix can be inscribed as $A = [A_L, A_U] = [a_{ijL}, a_{ijU}]$ where a_{ijL} = lower limit, a_{ijU} = upper limit.

For $A = [a_{ijL}, a_{ijU}]$ and $B = [b_{ijL}, b_{ijU}]$ is of order $m \times n$ in addition represented by $A+B$ distinct as $[A_L, A_U] + [B_L, B_U] = [a_{ijL}, a_{ijU}] + [b_{ijL}, b_{ijU}] = [a_{ijL} + b_{ijL}, a_{ijU} + b_{ijU}]$

and their multiplication can be defined as,

$$[A_L, A_U][B_L, B_U] = [A_L B_L, A_U B_U] = \left(\begin{bmatrix} c_{ijL} & c_{ijU} \end{bmatrix} \right)$$

$$= \left[\sum_i a_{ikL} b_{kjL}, \sum_k a_{ikU} b_{kjU} \right] \text{ for } i = 1, 2, \dots, m \text{ and } j = 1, 2, \dots, p$$

where $A = [A_L, A_U]_{m \times n}$ and $B = [B_L, B_U]_{n \times p}$

their product denoted by $[AB] = [A_L B_L, A_U B_U]_{m \times p}$. $A \geq B$ iff $a_{ijL} \geq b_{ijL}$ and $a_{ijU} \geq b_{ijU}$ iff $A+B=A$ In Specific if $a_{ijL}=a_{ijU}$ and $b_{ijL}=b_{ijU}$, as a result, given equation gives the standard incline matrices.

Theorem 2.5

For $[X_L, X_U][Y_L, Y_U] \in (L^1)_n$, then

- $[R(X_L), R(X_U)] = [R(Y_L), R(Y_U)]$ and $[R(X_L^k), R(X_U^k)] = [R(Y_L^k), R(Y_U^k)]$ then $[X_L, X_U]$ is right k -regular IIM $\Leftrightarrow [Y_L, Y_U]$ is right k -regular IIM.
- $[C(X_L), C(X_U)] = [C(Y_L), C(Y_U)]$ and $[C(X_L^k), C(X_U^k)] = [C(Y_L^k), C(Y_U^k)]$ then $[X_L, X_U]$ is left k -regular IIM $\Leftrightarrow [Y_L, Y_U]$ is left k -regular IIM.

Lemma 2.6

For $X = [X_L, X_U] \in (IIM)_{mn}$ and $Y = [Y_L, Y_U] \in (IIM)_{np}$, the following hold.

- $X^T = [X_L^T, X_U^T]$
- $XY = [X_L Y_L, X_U Y_U]$

Lemma 2.7

For $X, Y \in (IIM)_{mn}$

- $[R(Y_L), R(Y_U)] \subseteq [R(X_L), R(X_U)] \Leftrightarrow [Y_L, Y_U] = [X_L A_L, X_U A_U]$ for some $A \in (IIM)_m$.
- $[C(Y_L), C(Y_U)] \subseteq [C(X_L), C(X_U)] \Leftrightarrow [Y_L, Y_U] = [X_L B_L, X_U B_U]$ for some $B \in (IIM)_m$.

Inverses of k -Regular Interval Incline Matrices

In this section, we shall introduce the concept of k -g inverses associated with a k -regular interval incline matrix as an extension of k -g inverses of a k -regular fuzzy matrix and as a k -regular IVFM.

Definition 3.1

A matrix $T = [T_L, T_U] \in (L^1)_{mn}$ is said to be right k -regular if there exists a matrix $Y = [Y_L, Y_U] \in (IIM)_{n \times m}$, such that $[T_L^k Y_L T_L, T_U^k Y_U T_U] = [T_L^k, T_U^k]$ for some positive integer $k > 1$. $[Y_L, Y_U]$ is called a Right k -g-inverse of $T = [T_L, T_U]$. Let $[T_L, T_U]_k\text{-}\{1_r\} = \{[Y_L, Y_U] / [T_L^k Y_L T_L, T_U^k Y_U T_U] = [T_L^k, T_U^k]\}$.

Definition 3.2

A interval incline matrix $[T_L, T_U] \in (IIM)_n$ is said to be left k -regular if there exist a interval matrix $[B_L, B_U] \in (IIM)_n$, Such that $[T_L B_L T_L^k, T_U B_U T_U^k] = [T_L^k, T_U^k]$ for some Positive integer $k > 1$. $[B_L, B_U]$ is called a left k -g inverse of $T = [T_L, T_U]$.





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Let $[T_L, T_U]k-\{1_r\} = \{[B_L, B_U] / [T_L B_L T_L^k, T_U B_U T_U^k] = [T_L^k, T_U^k]\}$. In particular for a incline matrix $[T_L, T_U]$, that is $T_{ijL} = T_{ijU}$ then Definition (3.1) and Definition (3.2) reduce to right and left k -regular interval incline matrices respectively found in [14].

Definition 3.3

A interval incline matrix $[T_L, T_U] \in (IIM)_n$, is said to have a k -{3} inverse if there exists a interval matrix $[Y_L, Y_U] \in (IIM)_n$, such that $[(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [(T_L^k Y_L), (T_U^k Y_U)]$, for some positive integer $k > 1$. $[Y_L, Y_U]$ is called the of k -{3} inverse $[T_L, T_U]$. Let $[T_L, T_U]k-\{3\} = \{[Y_L, Y_U] / [(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [(T_L^k Y_L), (T_U^k Y_U)]\}$

Definitim 3.4

A interval incline matrix $[T_L, T_U] \in L_n$, is said to have a k -{4} inverse if there exists a interval matrix $Y = [Y_L, Y_U] \in (IIM)_n$, such that $[(Y_L T_L^k)^T, (Y_U T_U^k)^T] = [(Y_L T_L^k), (Y_U T_U^k)]$ for some positive integer $k > 1$. $[Y_L, Y_U]$ is called the of k -{4} inverse $[T_L, T_U]$. Let $[T_L, T_U]k-\{4\} = \{[Y_L, Y_U] / [(Y_L T_L^k)^T, (Y_U T_U^k)^T] = [(Y_L T_L^k), (Y_U T_U^k)]\}$

Remark 3.5

In perticular for $k=1$, Definition (3.3) and (3.4) reduces to set of {3} and {4} inverses respectively of a IIM and in the Case $T_L = T_U$ ($T_L \leq T_U$), Definition (3.3) and (3.4) reduces to the set of k -{3}, k -{4} inverses respectively of interval incline matrices.

Theorem 3.6

Let $T = [T_L, T_U] \in L_n$, then $[T_L, T_U]$ has a k -{3} inverse iff T_L and $T_U \in L_n$, have k -{3} inverses.

Proof

Let $T = [T_L, T_U] \in (IIM)_n$. Since $[T_L, T_U]$ has a k -{3} inverse, if there exists a interval matrix $[Y_L, Y_U] \in (IIM)_n$, Such that $[(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [(T_L^k Y_L), (T_U^k Y_U)]$

Let $Y = [Y_L, Y_U]$, then by Lemma (2.6) (ii), $(T^k Y)^T = (T^k Y)$

$$\Leftrightarrow [T_L^k Y_L, T_U^k Y_U]^T = [T_L^k Y_L, T_U^k Y_U]$$

$$\Leftrightarrow [(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [T_L^k Y_L, T_U^k Y_U]$$

$$\Leftrightarrow (T_L^k Y_L)^T = T_L^k Y_L \text{ and } (T_U^k Y_U)^T = T_U^k Y_U$$

Hence $[T_L, T_U] \in (IIM)_n$ has a k -{3} inverse iff T_L and $T_U \in L_n$, have k -{3} inverses.

Theorem 3.7

Let $T = [T_L, T_U] \in L_n$, then $[T_L, T_U]$ has a k -{4} inverse iff T_L and $T_U \in L_n$, have k -{4} inverses.

Proof

In similar manner of theorem (3.6) which can be proved.

Theorem 3.8

Let $[T_L, T_U] \in L_n$, and k be a positive integer $k > 1$, if

1. $[Y_L, Y_U] \in [T_L, T_U]k-\{1_i\}$ with $[\Re(Y_L), \Re(Y_U)] = [\Re(T_L^k Y_L), \Re(T_U^k Y_U)]$ then $[T_L, T_U] \in [Y_L, Y_U]k-\{1_i\}$
2. $[Y_L, Y_U] \in [T_L, T_U]k-\{1_i\}$ with $[C(Y_L), C(Y_U)] = [C(Y_L T_L^k), C(Y_U T_U^k)]$ then $[T_L, T_U] \in [Y_L, Y_U]k-\{1_r\}$

Proof

Since $[Y_L, Y_U] \in [T_L, T_U]k-\{1_i\}$ by Definition (3.2),

$$[(T_L^k Y_L T_L), (T_U^k Y_U T_U)] = [T_L^k, T_U^k]$$

$$\text{Since } [\cdot(Y_L), \cdot(Y_U)] = [\cdot(T_L^k Y_L), \cdot(T_U^k Y_U)]$$

by LemmY (2.7), $[Y_L, Y_U] = [B_L T_L^k Y_L, B_U T_U^k Y_U]$, for some $[B_L, B_U] \in (IIM)_n$

$$[Y_L T_L Y_L^k, Y_U T_U Y_U^k] = [B_L T_L^k Y_L T_L Y_L^k, B_U T_U^k Y_U T_U Y_U^k]$$

$$= [B_L T_L^k Y_L^k, B_U T_U^k Y_U^k]$$

$$= [B_L T_L^k Y_L Y_L^{k-1}, B_U T_U^k Y_U Y_U^{k-1}]$$





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$$=[Y_L Y_L^{k-1}, Y_U Y_U^{k-1}]$$

$$=[Y_L^k, Y_U^k]$$

Hence $[T_L, T_U] \in [Y_L, Y_U]k-\{1\}$

(ii) Proof is similar to (i) and hence omitted.

Example:

$$T = \begin{pmatrix} [1,1] & [0.5,0.3] & [0,0] \\ [0.5,0.5] & [1,1] & [0.5,0.5] \\ [0.5,0.3] & [0.5,0.3] & [1,1] \end{pmatrix}$$

$$Y = \begin{pmatrix} [1,1] & [0,0] & [0,0] \\ [0.5,0.3] & [1,1] & [0.5,0.3] \\ [0,0] & [0,0] & [1,1] \end{pmatrix}$$

$$TYT = \begin{pmatrix} [1,1] & [0.5,0.3] & [0.5,0.3] \\ [0.5,0.5] & [1,1] & [0.5,0.5] \\ [0.5,0.3] & [0.5,0.3] & [1,1] \end{pmatrix}$$

$$= \begin{pmatrix} [1,1] & [0.5,0.3] & [0.5,0.3] \\ [0.5,0.5] & [1,1] & [0.5,0.5] \\ [0.5,0.3] & [0.5,0.3] & [1,1] \end{pmatrix} \neq T$$

$T^3 XT = T^3$. Hence T is 3-regular.

For $k=3$, $T^3 XT = T^3$ but $T^3 XT \neq T^3$

Hence, T is a right 3-g inverse but not a left 3-g-inverse.

Theorem 3.9

For $[T_L, T_U] \in L_n$, and for any $G=[G_L, G_U] \in (IIM)_n$ if $[T_L^k Y_L, T_U^k Y_U] = [T_L^k G_L, T_U^k G_U]$ where $[Y_L, Y_U]$ is a $k-\{1_r, 3\}$ inverse of $[T_L, T_U]$. then $G=[G_L, G_U]$ is a $k-\{1_r, 3\}$ inverse of $[T_L, T_U]$.

Proof

Since $[Y_L, Y_U]$ is a $k-\{1_r, 3\}$ inverse of $[T_L, T_U]$ by Definition (3.2) and (3.3) $[T_L^k Y_L T_L, T_U^k Y_U T_U] = [T_L^k, T_U^k]$ and $[(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [(T_L^k Y_L), (T_U^k Y_U)]$ Post multiplying by $[T_L, T_U]$ on both sides of $[T_L^k Y_L, T_U^k Y_U] = [T_L^k G_L, T_U^k G_U]$

We get, $[T_L^k Y_L T_L, T_U^k Y_U T_U] = [T_L^k G_L T_L, T_U^k G_U T_U] = [T_L^k, T_U^k] = T^k$

Since $[T_L^k Y_L, T_U^k Y_U] = [T_L^k G_L, T_U^k G_U]$

$\Rightarrow [(T_L^k G_L)^T, (T_U^k G_U)^T] = [(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [(T_L^k Y_L), (T_U^k Y_U)] = [T_L^k G_L, T_U^k G_U] = T^k G$

Hence $G=[G_L, G_U]$ is a $k-\{1_r, 3\}$ inverse of $[T_L, T_U]$.

Theorem 3.10

For $[Y_L, Y_U] \in (IIM)_n$, then for only $G=[G_L, G_U] \in (IIM)_n$ if $[(Y_L T^k_L), (Y_U T^k_U)] = [(G_L T^k_L), (G_U T^k_U)]$ where $[Y_L, Y_U]$ has a $k-\{1_i, 4\}$ inverse of $[T_L, T_U]$. then $G=[G_L, G_U]$ is a $k-\{1_i, 4\}$ inverse of $[T_L, T_U]$.

Proof

Proof is similar to that of theorem(3.9) and hence omitted.





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Theorem 3.11

For $[T_L, T_U] \in L^n$, $[Y_L, Y_U]$ is a k - $\{1, 4\}$ inverse of $[T_L, T_U]$ and $[G_L, G_U]$ is a k - $\{1, 4\}$ inverse of $[T_L, T_U]$. then $[Y_L T^k_L, Y_U T^k_U] = [G_L T^k_L, G_U T^k_U]$

Proof

This can be proved in the similar manner as that of Theorem(3.10) and hence omitted.

In general, for an IIM $[T_L, T_U]$, there is no relation between k -regularity of $[T_L, T_U]$, $[T^k_L T_L, T^k_U T_U]$ and $[T_L T^k_L, T_U T^k_U]$. Hence the relation shall be discussed under certain conditions on their row spaces.

Theorem 3.12

For $[T_L, T_U] \in L^n$, with $[\square(T_L), \square(T_U)] = [\square(T^k_L T_L), \square(T^k_U T_U)]$ and $[\square(T^k_L), \square(T^k_U)] = [\square(T_L T^k_L)^k, \square(T_U T^k_U)^k]$ then $[T_L, T_U]$ is right k -regular $\Leftrightarrow [T^k_L T_L, T^k_U T_U]$ is right k -regular.

Proof

This follows from Theorem(2.5) by replacing $[Y_L, Y_U]$ by $[T_L T^k_L, T_U T^k_U]$.

Theorem 3.13

For $[T_L, T_U] \in L^n$, with $[C(T_L), C(T_U)] = [C(T_L T^k_L), C(T_U T^k_U)]$ and $[C(T^k_L), C(T^k_U)] = [C(T_L T^k_L)^k, C(T_U T^k_U)^k]$ then $[T_L, T_U]$ is left k -regular $\Leftrightarrow [T_L T^k_L, T_U T^k_U]$ is left k -regular.

Proof

This follows from Theorem(2.5) by replacing $[Y_L, Y_U]$ by $[T_L T^k_L, T_U T^k_U]$.

Theorem 3.14

For $[T_L, T_U] \in L^n$, if $[T^k_L T_L, T^k_U T_U]$ is a right k -regular and $[\square(T^k_L), \square(T^k_U)] \subseteq [\cdot(T^k_L T_L), \cdot(T^k_U T_U)]$ then $[T_L, T_U]$ has a k - $\{1, 3\}$ inverse. In particular for $k=1$, $[B_L, B_U] = [(T^k_L T_L)^{-1} T^k_L, (T^k_U T_U)^{-1} T^k_U]$ is a $\{1, 3\}$ inverse of $[T_L, T_U]$.

Proof

Since $[T^k_L T_L, T^k_U T_U]$ is a right k -regular IIM by Definition (3.1)

$[(T^k_L T_L)^k (T^k_L T_L)^{-1} (T^k_L T_L), (T^k_U T_U)^k (T^k_U T_U)^{-1} (T^k_U T_U)] = [(T^k_L T_L)^k, (T^k_U T_U)^k]$ for some right k -g inverse $[(T^k_L T_L)^{-1}, (T^k_U T_U)^{-1}]$ of $[T^k_L T_L, T^k_U T_U]$. Since $[\cdot(T^k_L), \cdot(T^k_U)] \subseteq [\cdot(T^k_L T_L)^k, \cdot(T^k_U T_U)^k]$, by Lemma (2.7),

$[T^k_L, T^k_U] = [Y_L, Y_U][\cdot(T^k_L T_L)^k, \cdot(T^k_U T_U)^k]$ for some $[Y_L, Y_U] \in (IIM)_n$ and take $[B_L, B_U] = [(T^k_L T_L)^{-1} T^k_L, (T^k_U T_U)^{-1} T^k_U]$ $[T^k_L B_L T_L, T^k_U B_U T_U] = [T^k_L (B_L T_L), T^k_U (B_U T_U)]$

$= [(Y_L (T^k_L T_L)^k (T^k_L T_L)^{-1} (T^k_L T_L)), (Y_U (T^k_U T_U)^k (T^k_U T_U)^{-1} (T^k_U T_U))]$

$= [Y_L, Y_U][((T^k_L T_L)^k (T^k_L T_L)^{-1} (T^k_L T_L)), ((T^k_U T_U)^k (T^k_U T_U)^{-1} (T^k_U T_U))]$

$= [Y_L, Y_U][((T^k_L T_L)^k), ((T^k_U T_U)^k)]$

$= [T^k_L, T^k_U]$ and take $Z = [Z_L, Z_U] = [(T^k_L T_L)^{-1} (T^k_L)^T, (T^k_U T_U)^{-1} (T^k_U)^T]$

$[T^k_L Z_L, T^k_U Z_U] = [(Y_L (T^k_L T_L)^k (T^k_L T_L)^{-1} (T^k_L)^T), (Y_U (T^k_U T_U)^k (T^k_U T_U)^{-1} (T^k_U)^T)]$

$= [Y_L, Y_U][((T^k_L T_L)^k (T^k_L T_L)^{-1} (T^k_L T_L)^k), ((T^k_U T_U)^k (T^k_U T_U)^{-1} (T^k_U T_U)^k)][Y_L, Y_U]^T$

$= [Y_L, Y_U][((T^k_L T_L)^k (T^k_L T_L)^{-1} (T^k_L T_L)^{k-1} T^k_L, (T^k_U T_U)^k (T^k_U T_U)^{-1} (T^k_U T_U)^{k-1} T^k_U) [Y_L, Y_U]^T$

$= [Y_L, Y_U][((T^k_L T_L)^k (T^k_L T_L)^{k-1}, (T^k_U T_U)^k (T^k_U T_U)^{k-1})][Y_L, Y_U]^T$

$= [(Y_L, Y_U)[((T^k_L T_L)^{2k-1}, (T^k_U T_U)^{2k-1})][Y_L, Y_U]^T$

$= [(T^k_L Z_L), (T^k_U Z_U)]^T [T^k_L Z_L, T^k_U Z_U] = [(T^k_L Z_L), (T^k_U Z_U)]^T$

Hence $[T_L, T_U]$ has a k - $\{1, 3\}$ inverse. In particular for $k=1$, $[B_L, B_U] = [(T^k_L T_L)^{-1} T^k_L, (T^k_U T_U)^{-1} T^k_U]$ is a $\{1, 3\}$ inverse of $[T_L, T_U]$.

Theorem 3.15

For $[T_L, T_U] \in (IIM)_n$, if $[T_L T^k_L, T_U T^k_U]$ is left k -regular IIM and

$[C(T^k_L), C(T^k_U)] \subseteq [C(T_L T^k_L)^k, C(T_U T^k_U)^k]$ then $[T_L, T_U]$ has a k - $\{1, 4\}$ inverse. In particular for $k=1$, $[Z_L, Z_U] = [T^k_L (T^k_L T_L)^{-1}, T^k_U (T^k_U T_U)^{-1}]$ is a $\{1, 4\}$ inverse of $[T_L, T_U]$.





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Proof

Proof is similar to Theorem(3.14) and hence omitted.

Theorem 3.16

For $[T_L, T_U] \in (IIM)_n$, be a right k - regular IIM and $[\square(T^T_L T_L)^k, \square(T^T_U T_U)^k] \subseteq [\cdot(T^k_L), \cdot(T^k_U)]$ then $[T^T_L T_L, T^T_U T_U]$ has a k -{3} inverse.

Proof

Since $[T_L, T_U] \in (IIM)_n$, be a right k - regular IIM By Definition (3.1) $[T^T_L Y_L T_L, T^T_U Y_U T_U] = [T_L^k, T_U^k]$ for some right k - g inverse $[Y_L, Y_U] \in (IIM)_n$ of $[T_L, T_U]$. Since $[\cdot(T^T_L T_L)^k, \cdot(T^T_U T_U)^k] \subseteq [\cdot(T^k_L), \cdot(T^k_U)]$ by Lemma (2.7),

$$[(T^T_L T_L)^k, (T^T_U T_U)^k] = [Z_L T^k_L, Z_U T^k_U] \text{ for some } [Z_L, Z_U] \in (IIM)_n \text{ and take } [B_L, B_U] = [Y_L T_L, Y_U T_U] \quad [(T^T_L T_L)^k B_L, (T^T_U T_U)^k B_U] = [(Z_L T^k_L)(Y_L T_L), (Z_U T^k_U)(Y_U T_U)]$$

$$= [Z_L T^k_L Y_L T_L, Z_U T^k_U Y_U T_U]$$

$$= [Z_L T^k_L, Z_U T^k_U]$$

$$= [(T^T_L T_L)^k, (T^T_U T_U)^k]$$

$$= [((T^T_L T_L)^k, (T^T_U T_U)^k)]^T$$

$$= [((T^T_L T_L)^k B_L, (T^T_U T_U)^k B_U)]^T$$

Hence $[T^T_L T_L, T^T_U T_U]$ is a k -{3} inverse.

Theorem 3.17

Let $[T_L, T_U] \in (IIM)_n$, be a left k - regular IIM and $[C(T_L T^T_L)^k, C(T_U T^T_U)^k] \subseteq [C(T^k_L), C(T^k_U)]$ then $[T_L T^T_L, T_U T^T_U]$ has a k -{4} inverse.

Proof

This can be proved in the same manner as that of Theorem(3.16) and hence omitted.

Theorem 3.18

For $[T_L, T_U] \in (IIM)_n$, $[Y_L, Y_U]$ is a k -{1, 3} inverse of $[T_L, T_U]$. and $[G_L, G_U]$ is a k -{1, 4} inverse of $[T_L, T_U]$ then $[T_L^k Y_L, T_U^k Y_U] = [T_L^k G_L, T_U^k G_U]$.

Proof

Since $[Y_L, Y_U]$ is a k -{1, 3} inverse of $[T_L, T_U]$ By Definition (3.1) and (3.3)

$$[(T_L^k Y_L T_L), (T_U^k Y_U T_U)] = [T_L^k, T_U^k] \text{ and } [(T_L^k Y_L)^T, (T_U^k Y_U)^T] = [(T_L^k Y_L), (T_U^k Y_U)]$$

Since $G = [G_L, G_U]$ is a k -{1, 3} inverse of $[T_L, T_U]$, by Definition (3.1) and Remark (3.5),

$$[(T_L G_L T_L^k), (T_U G_U T_U^k)] = [T_L^k, T_U^k] \text{ and } [(T_L G_L)^T, (T_U G_U)^T] = [(T G)_L, (T G)_U]$$

$$\Rightarrow [T_L^k G_L, T_U^k G_U] = [(T_L^k Y_L T_L) G_L, (T_U^k Y_U T_U) G_U]$$

$$= [(T_L^k Y_L)(T_L G_L), (T_U^k Y_U)(T_U G_U)]$$

$$= [(T_L^k Y_L)^T, (T_U^k Y_U)^T] [(T_L G_L)^T, (T_U G_U)^T]$$

$$= [(Y_L^T (T_L^T)^k, Y_U^T (T_U^T)^k) [G_L^T T_L^T, G_U^T T_U^T]]$$

$$= [(Y_L^T, Y_U^T) [(T_L G_L T_L^k)^T, (T_U G_U T_U^k)^T]]$$

$$= [(Y_L^T, Y_U^T) [(T_L^k)^T, (T_U^k)^T]]$$

$$= [(T_L^k Y_L)^T, (T_U^k Y_U)^T]$$

$$= [(T_L^k Y_L), (T_U^k Y_U)]$$

$$= T^k Y$$

Hence the theorem.

Theorem 3.19

Let $T \in L_{m,n}$, be a regular interval incline matrix, then

$$[T_L^{(1,4)} T_L T_L^{(1,3)}, T_U^{(1,4)} T_U T_U^{(1,3)}] = [T_L^+, T_U^+].$$



**Proof**

Let $[Z_L, Z_U] = [T_L^{(1,4)}T_L T_L^{(1,3)}, T_U^{(1,4)}T_U T_U^{(1,3)}]$
 $(TZ) = [T_L Z_L, T_U Z_U] = [T_L(T_L^{(1,4)}T_L T_L^{(1,3)}), T_U(T_U^{(1,4)}T_U T_U^{(1,3)})]$
 $= [(T_L T_L^{(1,4)}T_L)T_L^{(1,3)}, (T_U T_U^{(1,4)}T_U)T_U^{(1,3)}]$
 $= [T_L T_L^{(1,3)}, T_U T_U^{(1,3)}]$
 $(TZ)^T = [(T_L Z_L)^T, (T_U Z_U)^T] = [(T_L T_L^{(1,3)})^T, (T_U T_U^{(1,3)})^T]$
 $= [T_L T_L^{(1,3)}, T_U T_U^{(1,3)}]$
 $= [T_L Z_L, T_U Z_U] (ZT) = [Z_L T_L, Z_U T_U] = [(T_L^{(1,4)}T_L T_L^{(1,3)})T_L, (T_U^{(1,4)}T_U T_U^{(1,3)})T_U]$
 $= [T_L^{(1,4)}(T_L T_L^{(1,3)}T_L), T_U^{(1,4)}(T_U T_U^{(1,3)}T_U)]$
 $= [T_L^{(1,4)}T_L, T_U^{(1,4)}T_U]$
 $(ZT)^T = [(Z_L T_L)^T, (Z_U T_U)^T] = [(T_L^{(1,4)}T_L)^T, (T_U^{(1,4)}T_U)^T]$
 $= [T_L^{(1,4)}T_L, T_U^{(1,4)}T_U] = [Z_L T_L, Z_U T_U]$
 Thus $Z = [Z_L, Z_U] = [T_L^{(1,4)}T_L T_L^{(1,3)}, T_U^{(1,4)}T_U T_U^{(1,3)}] = [T_L^+, T_U^+]$
 Hence the Theorem .

CONCLUSION

We have extended the concept of incline to interval incline matrices as a generalization of IVFM. Interval of inverses of k -regular interval incline matrices. Some definitions for an g inverse of interval incline matrix to be inverse were studied. g -inverse k - $\{1_r, 3, 4\}$, k - $\{1_r, 3, 4\}$ and $\{1_k, 3^k, 4^k\}$ was established and the group of inverse interval incline matrices was investigated of IIMS.

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Design and Fabrication of a Manual Wire Stirrup Machine

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ABSTRACT

This research work focuses on the development of an economical technique for straightening 6mm Mild Steel bars. Currently, industries manually straighten commercial bars using a tedious and time-consuming hammering process. Automation is essential to improve efficiency. The construction industry relies on various wire products like stirrups, which are manufactured from coiled wire. The Manual Wire Straightening Cutting Stirrup Machine (MWSCSM) plays a vital role in the sequential operations of straightening, cutting, and shaping the wire into stirrups. The MWSCSM employs a stopper cutter head for wire cutting, limited by its length and feeding speed. Three power-driven vertical feed rolls facilitate the advancement of bar stock through horizontal and vertical rollers in different halves of the machine. During the process, autorotation and spring back effects were encountered. The autorotation issue is resolved with a three-roller standstill locking mechanism, enhancing straightening precision. Additionally, a parallel roller collocation scheme is introduced to eliminate auto-rotation, ensuring high-speed and scratch-free cold rolled deformed bars. To tackle the spring back effect, bidirectional loading is implemented, yielding improved results. The idler rolls are equipped with needle bearings, while the gear boxes are enclosed; housing hardened steel gears bathed in oil. As bar bending and stirrup making operations are essential in the construction industry, the usage of machines, whether manual, semi-automatic, or fully automatic, has become common in construction sites and workshops.

Keywords: Straightening Technique, Manual Wire Straightening Cutting Stirrup Machine (MWSCSM), Industrial Automation, Wire Products, Coil Form Straightening and Wire Rod Cutting





INTRODUCTION

The increasing demand in the construction industry for the development of bridges, buildings, and residential areas has highlighted the essential role of stirrups and bars in forming reinforcement structures, commonly known as shear reinforcement. These reinforcements are crucial for ensuring the structural integrity of buildings and other constructions, protecting them against failure caused by diagonal tension. Bar bending is a critical process in the construction industry, especially involving 6mm diameter bars used to create stirrups or bends. To meet the industry's demand for efficiency and cost-effectiveness, the Manual Wire Straightening Cutting Stirrup Machine (MWSCSM) has been ingeniously designed to reduce human efforts and increase productivity by minimizing the need for manual labor[1]. This versatile machine can extend wires from rolls or coils, straighten them, cut them to required lengths, and shape them manually into the desired stirrup size. The MWSCSM is equipped with a wide range of features to cater to diverse applications, and some models are specifically configured to handle various cold drawing wires and nonferrous metal wires, allowing for continuous cutting according to specific dimensional requirements[2]. The MWSCSM performs three fundamental processes: feeding, straightening, and cutting the wire. Its features encompass the ability to handle wires of different diameters, cater to various straightening needs, and offer cutting lengths tailored to individual project requirements. The machine incorporates standard feed rollers with gears to ensure efficient straightening and cutting operations.

Figure 1 illustrates the MWSCSM, demonstrating its ability to cut wires below 4mm in diameter, along with its corresponding working layout. In the building, construction, and maritime industries, round steel bars, particularly those with a minor diameter ($d \leq 6\text{mm}$), are extensively utilized [3,4]. The majority of these commercially available MS round bars do not contain any alloying elements and have a carbon content not exceeding 0.25%. While these bars can be used after straightening, traditional manual straightening techniques suffer from low productivity and cannot keep up with the demands of modern construction projects. To improve the straightening process for minor diameter bars, some researchers have introduced a parallel-roll straightening device that significantly enhances straightening speed. However, this device has its limitations, as it allows the bar to rotate during the straightening process, resulting in reduced straightening accuracy. To overcome these limitations, this research paper proposes a revolutionary roll-layout of an equivalent curvature standstill-locking cum bidirectional straightening system, designed to achieve higher accuracy in straightening these minor diameter bars [5,6]. The mechanism is carefully analyzed for deformation and stress distribution using advanced Finite Element Software ANSYS, ensuring the reliability and efficiency of the proposed straightening system. In conclusion, the construction industry's increasing demand for sturdy and reliable structures has driven the development of advanced technologies, such as the Manual Wire Straightening Cutting Stirrup Machine (MWSCSM).

This innovative machine, equipped with versatile features and capabilities, has significantly reduced human effort and increased productivity in the construction process. Furthermore, the proposed equivalent curvature standstill-locking cum bidirectional straightening system represents a breakthrough in straightening minor diameter bars with enhanced accuracy, contributing to the overall efficiency and quality of reinforcement structure formation in the construction industry. Upon reviewing the literature on the design and production of machinery and wire forming machines for various industrial applications, several researchers have focused on improving the efficiency and productivity of stirrup making machines. Anbumeenakshi et al. developed a mechanically powered hydraulic bending machine capable of producing multiple stirrups simultaneously. This machine, equipped with hydraulic systems, offers ease of use and can create different types of stirrups using fixtures with varying dimensions and geometries. While it can produce 20 pieces of stirrups in 15 minutes, the initial workpiece cutting and positioning require manual intervention [6]. Virani et al. highlight the significant role of labor in the construction of structures, particularly in tying together the horizontal and vertical rods in columns or beams to support the concrete. Traditionally, workers manually bend stirrups in square or trapezoidal shapes and tie them using tight wires. However, this process requires considerable human effort, and automation is essential to reduce construction lead time and increase the stirrup bending rate. To address this need, the authors propose the "Automated Stirrup



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Bending Mechanism" (ASBM), which utilizes principles of hydraulics and electronics to enhance efficiency, reduce labor costs, and improve the accuracy of producing various sizes of stirrups [1,7,8]. Thokale et al. aimed to implement a cost-effective pneumatic rod bending machine at construction sites, enhancing stirrup productivity. Their design consists of pneumatic equipment, where the rod is bent by a pneumatic cylinder while being held in a fixture [9]. A significant advantage of this design is that the square-shaped stirrups can be continuously bent without the need for repositioning the rod in the machine [10]. Gujar et al. developed a unique approach using a Scotch Yoke Mechanism to convert the reciprocating motion of a pneumatic cylinder into rotary motion. When the motor feeds the rod, limit switches are activated, signaling the motor to stop quickly and activate the direction control valve, which operates the pneumatic cylinder and the Scotch yoke mechanism. This mechanism ensures efficient rod bending during stirrup forming, which continues until completion [11,12]. Waghmare et al. sought to improve stirrup making efficiency and production capacity by introducing a Human Powered Flywheel Motor (HPFM) system similar to a bicycle. In this system, a human spins a flywheel at approximately 600 RPM to store energy, which is then utilized in the stirrup making process to enhance production [13]. Vadaliya Darshit et al. focused on designing and constructing a high-production-rate machine that requires less manual labor while ensuring desired accuracy in stirrup manufacturing. Moreover, the studies discussed in the literature aim to address the challenges in stirrup making, such as labor-intensive processes and limited productivity. These innovative approaches offer potential solutions to improve efficiency, reduce manual effort, and increase the production capacity of stirrups in various industrial settings [14]. The primary objective of the research work is to reduce the reliance on human labor in the bar bending process. Traditional manual bar bending methods can be time-consuming, labor-intensive, and prone to errors. By introducing automation and advanced technologies, the aim is to streamline the bar bending operations and minimize the need for manual intervention. This will not only increase efficiency but also improve safety and the quality of reinforcement structures. Another key objective is to enhance productivity in the bar bending process [15]. Productivity is a crucial factor in construction projects, as the ability to produce a large number of accurately bent bars in a shorter timeframe directly impacts project timelines and cost-efficiency. By increasing productivity, construction companies can meet deadlines, take on larger projects, and remain competitive in the market. The objectives of this project focus on leveraging automation and advanced technologies to minimize human labor and maximize productivity in the bar bending process. By achieving these goals, the construction industry can optimize operations, improve efficiency, and deliver high-quality reinforcement structures more effectively [9].

MATERIALS AND METHODS

Several SPM (Special Purpose Machine) manufacturers are dedicated to achieving the same goal of enhancing productivity and reducing costs in the construction industry. While many have developed advanced machines, these tend to be expensive and often need to be imported. The aim of this project is to create an in-house, cost-effective machine. Similar to multi-forming machines, these machines also feature wire feeders in the form of rollers, which are connected to encoders through feeding rollers [15,16]. As depicted in the layout of the Manual Wire Straightening Cutting Stirrup Machine (MWSCSM), it consists of essential components such as the paying-off unit, feeding unit, straightening unit, and cutting head with a cut-off unit. In the paying-off unit, the wire can be supplied from a process such as a draw block or, more commonly, from a reel. The reel can be mounted on either a vertical or horizontal spindle. The vertical spindle is suitable for wires approximately 2 mm to 6 mm in diameter. In the feeding unit, the wire is typically fed using grooved feeding rolls or "pinch rolls." These rolls are powered and pinch or squeeze the material, pulling and/or pushing the wire through the machine. The feeding pressure on the rolls can be manually adjusted using cams or springs. Figure 2 illustrates the feed roller and its arrangement within the machine. The straightening process aims to eliminate and remove stresses induced into the material during its manufacture due to force and torque-related influences. This process is applicable to wire straightening, tube straightening, cable straightening, strip, and profile shape straightening. The roll straightener consists of a series of offset rolls that bend the wire beyond its elastic limit multiple times in two or more planes as the wire passes through. The rolls are adjustable, and the straightness achieved depends on the skill of the operator making the adjustments [17]. Following the straightening process is the "cutting off" or shearing process. Once the coiled wire is straightened, the machine





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includes an extended measurable stopper where the required length of wire can be measured and cut using a strong blade attached vertically to the main frame via a spring. Finally, the cut wire or rod is shaped using guided blocks on the frame, with the help of a fulcrum, to achieve the desired shape of the stirrup [18].

MATERIALS

Mild Steel Square/Round Bars

Mild steel, also known as "low carbon steel," contains a low amount of carbon, typically ranging from 0.05% to 0.25% by weight. In contrast, higher carbon steels have carbon content between 0.30% and 2.0%. Common uses of mild steel include structural steel, signs, automobiles, furniture, decoration, wire, fencing, and nails [5].

Gears

Gears are utilized to transmit motion from one shaft to another or between a shaft and a slide by successively engaging their teeth. This process does not involve any intermediate links or connectors, as gears transmit motion through direct contact. The surfaces of the two interacting gears make tangential contact, allowing for either rolling or sliding motion along the tangent at the point of contact. In our project, gears are employed to transmit motion between the shaft and the DC generator[1,15].

Shafts

A shaft is a rotating machine element used to transmit power from one location to another. Power is delivered to the shaft by a tangential force, and the resultant torque (or twisting moment) generated within the shaft allows the power to be transferred to various machines connected to it[8]. Two significant types of shafts are crucial in this context: transmission shafts and machine shafts. Transmission shafts are responsible for transferring power from the source to machines that absorb power and carry machine parts like pulleys and gears, subjecting them to both twisting and bending forces. Machine shafts form an integral part of the machine itself, such as the crankshaft [3]. By selecting the appropriate material and design, shafts can efficiently perform their intended functions, ensuring the reliability and performance of mechanical systems.

Standard Sizes of Transmission Shafts

The standard sizes of transmission shafts are specified to meet various mechanical and structural requirements. These sizes are as follows:

- 25 mm to 60 mm in 5 mm increments,
- 60 mm to 110 mm in 10 mm increments,
- 110 mm to 140 mm in 15 mm increments,
- 140 mm to 500 mm in 20 mm increments.

Additionally, the standard lengths of these shafts are typically 5 meters, 6 meters, and 7 meters[3].

Stresses in Shafts

Shafts are subjected to various stresses during operation, including:

- **Stresses due to the transmission of torque:** These stresses, also known as torsional loads, are induced when the shaft transmits power from one component to another.
- **Bending stresses:** These can be either tensile or compressive and arise from forces acting upon machine elements like gears and pulleys, as well as from the weight of the shaft itself.
- **Stresses due to combined torsion and bending loads:** Shafts often experience simultaneous torsional and bending stresses, requiring careful design and material selection to ensure durability and performance [21-24].

Bearings

A bearing is a critical machine element that supports the motion of another component while allowing relative movement between the contact surfaces. It bears the load, reduces friction, and facilitates smooth and efficient





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operation. Bearings come in various types and designs, tailored to specific applications and load requirements (Figure 3). Bearings play an essential role in enhancing the lifespan and reliability of machinery by ensuring smooth rotation and minimizing wear and tear. Selecting the appropriate shaft material and understanding the stresses involved are crucial for the design and performance of transmission shafts. Standardized shaft sizes and lengths ensure compatibility and ease of replacement across various applications. Bearings further enhance the functionality of shafts by providing necessary support and reducing friction, thereby ensuring smooth and reliable operation of mechanical systems. By adhering to these standards and considerations, engineers can design more efficient and durable transmission systems, ultimately leading to improved performance and longevity of machinery.

Roller (V-Grooved)

V-groove pulleys are efficient mechanical devices that facilitate power transmission between axles using a trapezoidal cross-section v-belt. This transmission solution ensures resistance against slipping and misalignment, enabling high-speed power transmission capabilities. The V-grooves, typically set at angles between 32° to 38°, can be measured using different-sized pins or discs. These pulleys incorporate precision ball bearings, lubricated for extended durability. The High-Speed Cartridge Assembly is compatible with any straightener and roller size or groove shape[1,15-20]. It incorporates two pre-loaded bearings, significantly enhancing straightener performance at high line speeds by reducing roller wobble (Figure 4).

Model Fabrication

A mechanical model refers to a physical representation or replica of a machine, system, or structure, designed to demonstrate its working principles and functions. Mechanical models play a crucial role in the design and development process, allowing engineers and designers to test and optimize their ideas before moving on to full-scale production. Additionally, mechanical models serve as valuable educational tools, enabling students and enthusiasts to grasp intricate engineering concepts and gain a hands-on understanding of how different machines and systems operate[20-24]

RESULTS AND CALCULATIONS

Observation and Analysis of Man-Hour Requirements in Production Methods

Traditional Method

An observation was conducted to determine the total man-hours required using the traditional method of production. The data revealed that:

- **Number of Workers:** 3 men
- **Total Components Produced:** 294 components per hour
- **Average Production Rate per Worker:** 98 components per hour per man

Present Machine-Assisted Method

The current method, which involves the use of a machine, showed the following results:

- **Number of Workers:** 2 men
- **Total Components Produced:** 480 components per hour
- **Average Production Rate per Worker:** 240 components per hour per man

Comparative Analysis

The comparison of these two methods indicates a significant improvement in productivity with the machine-assisted method. Here's the breakdown:

1. **Traditional Method Productivity:**
 - 3 men produce 294 components per hour.
 - Average productivity per man: 98 components per hour.
2. **Machine-Assisted Method Productivity:**





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- 2 men produce 480 components per hour.
- Average productivity per man: 240 components per hour.

This efficiency ratio of approximately 2.45 indicates that each worker in the machine-assisted method is 2.45 times more productive compared to the traditional method. The significant increase in productivity implies that the manpower required in the traditional method can be substantially reduced when adopting the machine-assisted method. Specifically, the production capacity achieved by 3 men in the traditional method can now be achieved by fewer men using the present machine-assisted method, leading to:

- Reduced labor costs
- Increased overall efficiency
- Potential for reallocating labor to other tasks or reducing total workforce

By leveraging machine-assisted production, the organization can optimize its resources and improve its production capabilities effectively.

CONCLUSION

The results of this study show that presently rod bending and stirrups making operations are essential operations in the construction industry. Bar bending & the stirrup-making machine is a type of equipment that makes the bending and stirring of bars, pipes, and other similar structures. It is one of the most common forms of mechanical bending in the steel industry. It is found that many individuals are involved in this process, from erecting the machinery to the worker operating it. The comparison between the Traditional method and the Manual Wire Straightening Cutting Stirrup Machine clearly demonstrates the advantages of automation in construction processes. The manual method requires three workers to achieve a certain output, whereas the machine accomplishes the same amount of work with just one worker. This substantial reduction in labor requirements leads to increased efficiency and productivity in construction projects. By utilizing the Manual Wire Straightening Cutting Stirrup Machine, construction companies can optimize their workforce and allocate manpower more effectively. The freed-up workers can be assigned to other critical tasks, resulting in better resource utilization and faster project completion. Additionally, the machine's precision and consistent performance contribute to improved accuracy and quality of the stirrup production, which is crucial for ensuring the structural integrity of buildings and other constructions. In conclusion, the implementation of the Manual Wire Straightening Cutting Stirrup Machine offers significant benefits, including reduced labor costs, enhanced efficiency, and improved production capacity. As automation continues to revolutionize the construction industry, embracing advanced technologies like this machine can lead to better overall construction practices and outcomes.

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Table 1: Standard Sizes of Transmission Shafts

Diameter Range (mm)	Increment (mm)
25 to 60	5
60 to 110	10
110 to 140	15
140 to 500	20

Table 2: Cost analysis of the whole model

Material Accessories	Cost(₹)
Square Frame (50×50)mm	5600
Spur Gear	3200
Blade	3000
Pulley	7200
Miscellaneous Expenses	6000
Total	25000

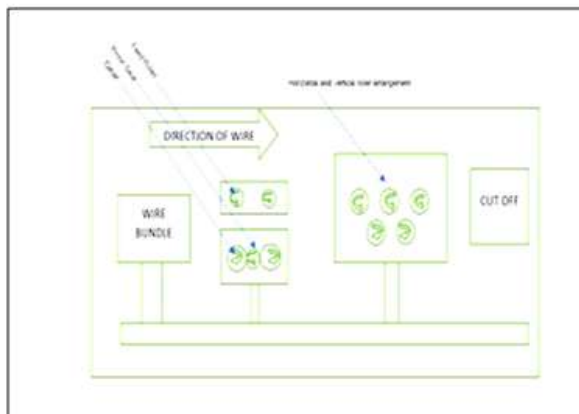


Fig.1 MWSCSM Working layout

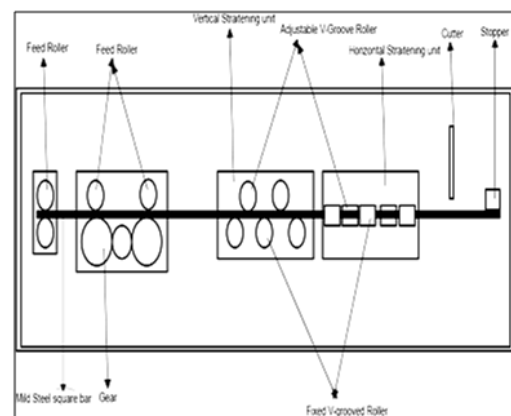


Figure 2: Block diagram of the model



Fig.3 Rolling Contact Bearing

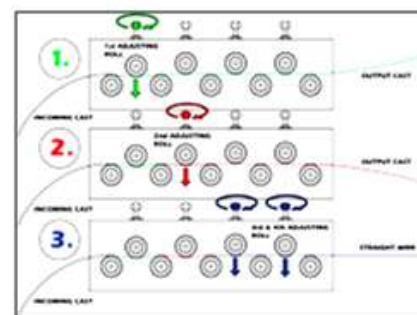


Fig 4: V-Groove roller arrangement with screw adjustment for the model



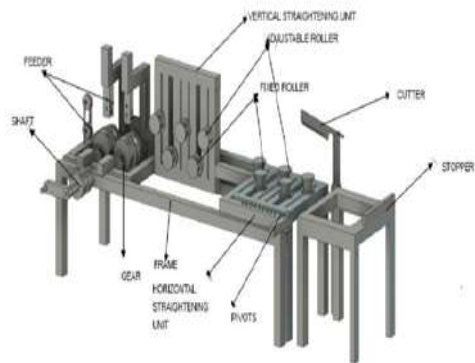


Fig 5: Pictorial view of the model

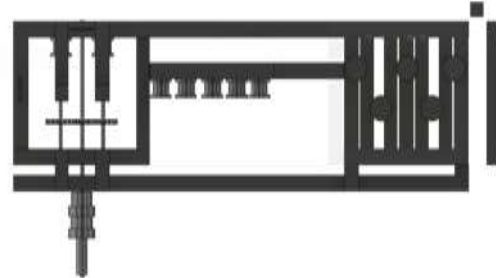


Fig 6: Model (Top View)

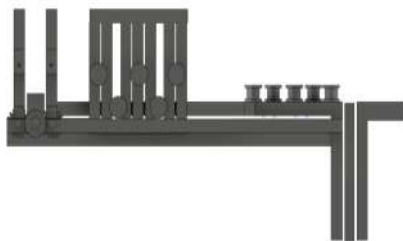


Figure 7: MODEL (FRONT VIEW)

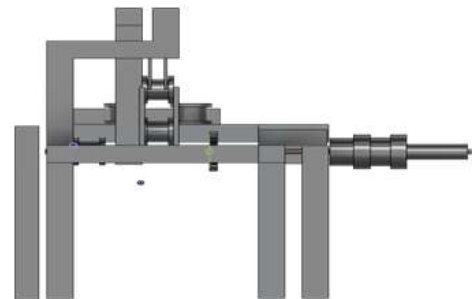


Figure 8: Model (Left View)



Figure 9: Gear and Pinion



Figure 10: Big Feeder





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Figure 11: Vertical Straighter



Figure 12: First Feeder



Figure 13: Horizontal Straighter





Comparability of Generalized Half Companion Sequences of Dio- 3 Tuples and Special Dio-3 Tuples using Hex Numbers

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ABSTRACT

The main purpose of this paper is to compare the behavior of two generalized half companion sequences comprising of Diophantine and special Diophantine triplets formed using Hex numbers of various ranks and the non-extendibility of such triplets to quadruples is proved using some theorems. This paper is an extended version of the paper[13] in which centered Triacontagonal number is replaced by Hex number and the comparison is made between two kinds of Dio-triples. To find the Diophantine triples, there is no specific method whereas the concept of Pellian equation is introduced for generating the triplets. The half companion sequences are constructed by Dio-triplets and special Dio-triplets using Hex numbers $Hex_r, Hex_{r+d}, Hex_{r-d}$ with distinct properties. The behavior of two such sequences are analyzed using MATLAB.

Keywords: Hex numbers, Dio-3 tuples, Special Dio-3 tuples, Non-Extendibility, perfect square.

MSC Code: 11B83, 11D99

INTRODUCTION

Diophantine equations are very famous among all Number theorist and have tremendous applications in the field of Cryptography and Network security. Many Diophantine equations are being solved by many researchers day to day. The concept of constructing the Diophantine triples and special Diophantine triples is a fascinating one. Diophantus





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of Alexandria discovered the set of numbers $q_1 = \frac{1}{16}, q_2 = \frac{33}{16}, q_3 = \frac{68}{16}, q_4 = \frac{105}{16}$ which satisfies the constraint $q_i q_j = S^2 - 1, \forall i, j = 1, 2, 3, 4$ where S denotes the rational number. Numerous studies have been conducted on the formation of an integer sequence. Any Diophantine triple, whose second largest element lies between the square and four times the square of the smallest one, can be uniquely extended to a Diophantine quadruple by attaching an element that is larger than the largest element in the triple, as demonstrated in the primary theorem proved by Cipu M, Filipin A, Fujita Y [1]. Park J [2] found the solution of Pellian equation which is developed by the $D(-1)$ triplets and he proved the extensibility of $D(-1)$ pair under some constraints using this previous result. Adzaga N, Filipin A, Jurasic A. [3] discovered that the set $\{2, b, c\}$ cannot be extended to irregular Dio-4 tuples for $2 < b < c$. But they accomplished some families of c 's which will depend on b 's. Adzaga N, Dujella A, Kreso D, Tadic P [4] established the result that there are infinite families of Dio-triples which are $D(n)$ -triples for two distinct as well as three distinct " n " with $n \neq 1$. Rihane SE, Luca F, Togbe A. [5] established that there are no Diophantine 4 tuples formed by pell numbers. Zhang and Grossman [6] established necessary and sufficient criteria for the existence of integer z' by taking into account the Diophantine triples $\{e_1, e_2, e_3\}$ such that $e_k e_j + z'^2 = c^2, j, k = 1, 2, 3$ and $\forall k \neq j$ where $z' \in \mathbb{Z}$. Basic and Filipin [7] discovered the extensibility of $D(4)$ pairings using a pellian equation; however, Earp – Lynch [8] extended their findings to differentiate between the solutions of pellian equations corresponding to $D(l^2)$ dio-3 tuples. Bonciocat NC, Cipu M, Mignotte M. [9] made an innovative study on Diophantine quadruples. With the additional requirement that $b_1 < b_2 < b_3$ with $b_1 = 3b_2$, Adedji KN, He B, Pinter A, Togbe A. [10] addressed the extensibility of the Diophantine 3-tuple $\{b_1, b_2, b_3\}$ and came at a the conclusion that a quadruple cannot be created from such a set. Additionally, they demonstrated the regularity of every Diophantine triple that contains the combination $\{b_1, 3b_2\}$ and found the same conclusion for $b_2 = 8b_1$. Saranya C, Janaki G. [11] established the half companion sequences of special Diophantine triplets that are formed using centered square numbers of ranks $n, n+1, n+2, n+3$ whereas Sangeetha V, Anupreethi T, Somanath M. [12] constructed the special Dio triples for various types of numbers of few ranks. The authors [13] deals with the centered Triacontagonal number. In this paper, the generalized half companion sequence of both Diophantine and special Diophantine triples using hex numbers of generalized ranks are established in the upcoming sections.

2. METHODOLOGY

Definition 2.1: A centered Hexagonal number, often known as a hex number is a figurate number which depicts a hexagon with a dot in the middle and all the other dots are arranged around the central dot in a hexagonal lattice. Hex_s denotes the hex numbers of rank $s \in \mathbb{N}$ and is given by

$$Hex_s = 3s^2 + 3s + 1$$

1, 7, 19, 37, 61, 91, 127, ... are first few hex numbers.

Definition 2.2: A sequence of integers (f_1, f_2, \dots, f_p) forms a Diophantine p -tuple with the property $D(\Lambda)$ if $f_i f_k + \Lambda = S^2, \forall j, k = 1, 2, \dots, p$ with $k \neq j$ and $s \in \mathbb{Z}$.

Definition 2.3: A three distinct set of polynomials $\{\kappa_1, \kappa_2, \kappa_3\}$ whose coefficients belong to \mathbb{Z} with the property $D(\Lambda)$ such that $\kappa_m \kappa_n + \kappa_m + \kappa_n + \Lambda = \Delta^2$ for all $m, n = 1, 2, 3$ and $m \neq n$, generate a special Dio-triplet. Note that ' Λ ' indicates a non-zero integer or a polynomial with integer coefficients. A Dio-3 tuple (a, b, c) is obtained from the pair (a, b) satisfying the property $D(\Lambda)$, where $a, b, c \in \mathbb{Z}$. On solving the system $ac + \Lambda = \pi_1^2, bc + \Lambda = \pi_2^2$ on applying the transformations $\pi_1 = u_1 + av_1, \pi_2 = u_1 + bv_1$, the pellian equation is resulted as $u_1^2 - abv_1^2 = \Lambda - 1$, where ab is not a perfect square and $\Lambda - 1 \neq 0$. Similarly, a special Dio-triplet (α, β, γ) is generated from a pair (α, β) that satisfies the property $D(\Lambda)$, where α, β, γ are polynomials. Solving the system of equations $\alpha\gamma + \alpha + \gamma + \Lambda = S_1^2, \beta\gamma + \beta + \gamma + \Lambda = S_2^2$ by utilizing the transformations $S_1 = \Pi + (\alpha + 1)\epsilon$ and $S_2 = \Pi + (\beta + 1)\epsilon$, the pellian equation $\Pi^2 - (\alpha + 1)(\beta + 1)\epsilon^2 = \Lambda - 1$ is produced, where $(\alpha + 1)(\beta + 1)$ is not a perfect square and $\Lambda - 1 \neq 0$.





2.1. Sequences of Dio-triplets

Case 1(A): For the ranks $r, r+d$

Suppose that η_1 and η_2 denotes the hex numbers of rank r and $r+d$, then

$$\eta_1 = \text{Hex}_r = 3r^2 + 3r + 1 \quad (1)$$

$$\eta_2 = \text{Hex}_{r+d} = 3r^2 + 6rd + 3d^2 + 3r + 3d + 1 \quad (2)$$

The value of $\eta_1\eta_2 + 3r^2d + 3rd^2 + 3rd + d^2 + d$ becomes a perfect square by using the property $D(3r^2d + 3rd^2 + 3rd + d^2 + d)$. In order to find $\eta_3 \in \mathbb{N}$ with the help of η_1 and η_2 , proceed by considering η_3 such that the following equations hold

$$\eta_1\eta_3 + 3r^2d + 3rd^2 + 3rd + d^2 + d = \pi_1^2 \quad (3)$$

$$\eta_2\eta_3 + 3r^2d + 3rd^2 + 3rd + d^2 + d = \pi_2^2 \quad (4)$$

where π_1 and π_2 are assumed as $\pi_1 = u_1 + \eta_1 v_1$, $\pi_2 = u_1 + \eta_2 v_1$.

Eliminating η_3 from (3) and (4) raises

$$u_1^2 = 3r^2d + 3rd^2 + 3rd + d^2 + d + \eta_1\eta_2v_1^2 \quad (5)$$

Replacing the values of η_1 and η_2 in (5) provides the initial solution

$$u_1 = 3r^2 + 3r + 3rd + 2d + 1, \quad v_1 = 1.$$

Also, π_1 is obtained as

$$\pi_1 = 6r^2 + 6r + 3rd + 2d + 2 \quad (6)$$

With the help of (1), (3) and (6), η_3 can be detected as

$$\eta_3 = 12r^2 + 12r + 12rd + 3d^2 + 7d + 4 \quad (7)$$

$$\Rightarrow \eta_3 = 2(\text{Hex}_r + \text{Hex}_{r+d}) - 3d^2 + d$$

Now, choose $\eta_4 \in \mathbb{N}$ which satisfies the equations

$$\eta_2\eta_4 + 3r^2d + 3rd^2 + 3rd + d^2 + d = \theta_1^2 \quad (8)$$

$$\eta_3\eta_4 + 3r^2d + 3rd^2 + 3rd + d^2 + d = \theta_2^2 \quad (9)$$

Take $\theta_1 = g_1 + \eta_2 h_1$ and $\theta_2 = g_1 + \eta_3 h_1$

Again on eliminating η_4 from (8) and (9), one may get

$$g_1^2 = 3r^2d + 3rd^2 + 3rd + d^2 + d + \eta_2\eta_3h_1^2 \quad (10)$$

(10) leads to the initial solution, $g_1 = 6r^2 + 6r + 3d^2 + 9rd + 5d + 2$, $h_1 = 1$

This provides $\theta_1 = 9r^2 + 15rd + 6d^2 + 9r + 8d + 3$

Substitution of the known values in (8) gives

$$\eta_4 = 27r^2 + 27r + 36rd + 12d^2 + 20d + 9 \quad (11)$$

$$\Rightarrow \eta_4 = 3\text{Hex}_r + 6\text{Hex}_{r+d} - 6d^2 + 2d$$

Consider $\eta_5 \in \mathbb{N}$ such that

$$\eta_3\eta_5 + 3r^2d + 3rd^2 + 3rd + d^2 + d = \alpha_1^2 \quad (12)$$

$$\eta_4\eta_5 + 3r^2d + 3rd^2 + 3rd + d^2 + d = \alpha_2^2 \quad (13)$$

with $\alpha_1 = m_1 + \eta_3 n_1$ and $\alpha_2 = m_1 + \eta_4 n_1$. Similarly, solving (12) and (13) will give rise to the initial solution $m_1 = 18r^2 + 18r + 21rd + 6d^2 + 12d + 6$, $n_1 = 1$ and this further provides the value of α_1 as follows

$$\alpha_1 = 30r^2 + 30r + 33rd + 9d^2 + 19d + 10$$

η_5 can be obtained from (12) as

$$\eta_5 = 75r^2 + 75r + 90rd + 27d^2 + 51d + 25 \quad (14)$$

(14) can also be represented as

$$\eta_5 = 10\text{Hex}_r + 15\text{Hex}_{r+d} - 18d^2 + 6d$$

\therefore The generalized half companion sequence of Dio-3 tuples involving Hex numbers of ranks r , $r+d$ obtained using the property $D(3r^2d + 3rd^2 + 3rd + d^2 + d)$ is accomplished as

$$\{(\text{Hex}_r, \text{Hex}_{r+d}, 2\text{Hex}_r + 2\text{Hex}_{r+d} - 3d^2 + d), (\text{Hex}_{r+d}, 2\text{Hex}_r + 2\text{Hex}_{r+d} - 3d^2 + d, 3\text{Hex}_r + 6\text{Hex}_{r+d} - 6d^2 + 2d), (2\text{Hex}_r + 2\text{Hex}_{r+d} - 3d^2 + d, 3\text{Hex}_r + 6\text{Hex}_{r+d} - 6d^2 + 2d, 10\text{Hex}_r + 15\text{Hex}_{r+d} - 18d^2 + 6d), \dots\}.$$



**Case 1(B): For the ranks $r-d, r+d$**

Assume ζ_1 and ζ_2 as

$$\zeta_1 = \text{Hex}_{r-d} = 3r^2 - 6rd + 3d^2 + 3r - 3d + 1 \quad (15)$$

$$\zeta_2 = \text{Hex}_{r+d} = 3r^2 + 6rd + 3d^2 + 3r + 3d + 1 \quad (16)$$

It is observed that $\zeta_1 \zeta_2 - 3d^2$ turns to a perfect square. Consider a positive ζ_3 that satisfy the following equations with the assumptions $\tau_1 = p_1 + \zeta_1 t_1$ and $\tau_2 = p_1 + \zeta_2 t_1$.

$$\zeta_1 \zeta_3 - 3d^2 = \tau_1^2 \quad (17)$$

$$\zeta_2 \zeta_3 - 3d^2 = \tau_2^2 \quad (18)$$

Eradication of ζ_3 from (17) and (18) helps in finding the foremost solution $p_1 = 3r^2 - 3d^2 + 3r + 1$, $t_1 = 1$ which will further give $\tau_1 = 6r^2 + 6r - 6rd - 3d + 2$. Replacing all the obtained values in (17), one may find ζ_3 as

$$\zeta_3 = 2(\text{Hex}_{r-d} + \text{Hex}_{r+d}) - 12d^2$$

By following the similar procedure as in case (i), the value of ζ_4, ζ_5 can be found as

$$\zeta_4 = 3\text{Hex}_{r-d} + 6\text{Hex}_{r+d} - 24d^2$$

$$\zeta_5 = 10\text{Hex}_{r-d} + 15\text{Hex}_{r+d} - 72d^2$$

Thus, for the hex numbers of ranks $r-d, r+d$, the half companion sequence of Dio-3 tuples is obtained as

$$\{(\text{Hex}_{r-d}, \text{Hex}_{r+d}, 2\text{Hex}_{r-d} + 2\text{Hex}_{r+d} - 12d^2), (\text{Hex}_{r+d}, 2\text{Hex}_{r-d} + 2\text{Hex}_{r+d} - 12d^2, 3\text{Hex}_{r-d} + 6\text{Hex}_{r+d} - 24d^2), (2\text{Hex}_{r-d} + 2\text{Hex}_{r+d} - 12d^2, 3\text{Hex}_{r-d} + 6\text{Hex}_{r+d} - 24d^2, 10\text{Hex}_{r-d} + 15\text{Hex}_{r+d} - 72d^2), \dots\}$$

2.2. Sequences of special Dio-triplets**Case 2(A): For the ranks $r, r+d$**

Consider the hex numbers of rank $r, r+d$ as in (1) and (2). It is clear that the quantity $\eta_1 \eta_2 + \eta_1 + \eta_2 + 1 - 2d^2 + 3r^2d + 3rd^2 + 3rd + 2d$ is a perfect square. To find $\eta'_3 \in \mathbb{Z}_+$ using η_1 and η_2 which satisfies the equations

$$\eta_1 \eta'_3 + \eta_1 + \eta'_3 + 1 - 2d^2 + 3r^2d + 3rd^2 + 3rd + 2d = l_1^2 \quad (19)$$

$$\eta_2 \eta'_3 + \eta_2 + \eta'_3 + 1 - 2d^2 + 3r^2d + 3rd^2 + 3rd + 2d = l_2^2 \quad (20)$$

where $l_1 = e_1 + (\eta_1 + 1)f_1$ and $l_2 = e_1 + (\eta_2 + 1)f_1$.

Solving (19) and (20) by the removal of ζ'_3 produces

$$e_1^2 = -2d^2 + 3r^2d + 3rd^2 + 3rd + 2d + (\eta_1 + 1)(\eta_2 + 1)f_1^2$$

On substituting (19) and (20), the above equation will give rise to the initial solution

$$e_1 = 3r^2 + 3r + 3rd + 2d + 2, f_1 = 1 \quad (21)$$

(21) gives $l_1 = 6r^2 + 6r + 3rd + 2d + 4$ and replacing all the obtained values in (19), η'_3 is resulted as

$$\eta'_3 = 12r^2 + 12rd + 12r + 3d^2 + 7d + 7 \quad (22)$$

$$\text{ie, } \eta'_3 = 2(\text{Hex}_r + \text{Hex}_{r+d}) - 3d^2 + d + 3$$

Assume $m_1 = v_1 + (\zeta_2 + 1)w_1$ and $m_2 = v_1 + (\zeta_3 + 1)w_1$. Select $\eta'_4 \in \mathbb{Z}_+$ such that

$$\eta_2 \eta'_4 + \eta_2 + \eta'_4 + 1 - 2d^2 + 3r^2d + 3rd^2 + 3rd + 2d = m_1^2 \quad (23)$$

$$\eta'_3 \eta'_4 + \eta'_3 + \eta'_4 + 1 - 2d^2 + 3r^2d + 3rd^2 + 3rd + 2d = m_2^2 \quad (24)$$

From (23) and (24), value of v_1^2 can be found which will provide the initial solution $v_1 = 6r^2 + 9rd + 6r + 3r^2 + 5d + 4$, $w_1 = 1$.

With the help of this solution, l_1^2 can be depicted and the value of η'_4 is obtained by the substitution of the all known values in (23) as

$$\eta'_4 = 27r^2 + 27r + 36rd + 12d^2 + 20d + 17 \quad (25)$$

$$\Rightarrow \eta'_4 = 3\text{Hex}_r + 6\text{Hex}_{r+d} - 6d^2 + 2d + 8$$

Similarly, $\eta'_5 \in \mathbb{Z}_+$ can be obtained by using η'_3 and η'_4 by following the same procedure as above. It is found that

$$\eta'_5 = 75r^2 + 75r + 90rd + 27d^2 + 51d + 49 \Rightarrow \eta'_5 = 10\text{Hex}_r + 15\text{Hex}_{r+d} - 18d^2 + 30d + 20$$





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Thus $\{(\eta_1, \eta_2, \eta_3), (\eta_2, \eta_3, \eta_4), (\eta_3, \eta_4, \eta_5), \dots\}$ forms the generalized half companion sequence of special Dio-triples generated by hex numbers.

Case 2(B): For the ranks $r-d, r+d$

Assume ζ_1, ζ_2 as in (15) and (16). It is clear that $\zeta_1\zeta_2 + \zeta_1 + \zeta_2 - 15d^2 + 1$ is a perfect square.

Hence, to find $\zeta'_3 \in \mathbb{N}$ such that the following equations hold with the supposition $C_1 = j_1 + (\zeta_1 + 1)q_1$ and $C_2 = j_1 + (\zeta_2 + 1)q_1$

$$\zeta'_3\zeta'_1 + \zeta'_1 + \zeta'_3 - 15d^2 + 1 = C_1^2 \quad (26)$$

$$\zeta'_3\zeta'_2 + \zeta'_2 + \zeta'_3 - 15d^2 + 1 = C_2^2 \quad (27)$$

Eradicating ζ'_3 from the above two equations and proceeding further as same in the previous cases, one may find the values of ζ'_3, ζ'_4 and ζ'_5 as follows

$$\zeta'_3 = 2(\text{Hex}_{r-d} + \text{Hex}_{r+d}) - 12d^2 + 3 \quad (28)$$

$$\zeta'_4 = 3\text{Hex}_{r-d} + 6\text{Hex}_{r+d} - 24d^2 + 8$$

$$\zeta'_5 = 10\text{Hex}_{r-d} + 15\text{Hex}_{r+d} - 72d^2 + 20$$

Hence,

$\{(\text{Hex}_{r-d}, \text{Hex}_{r+d}, 2(\text{Hex}_{r-d} + \text{Hex}_{r+d}) - 12d^2 + 3), (\text{Hex}_{r-d}, 2(\text{Hex}_{r-d} + \text{Hex}_{r+d}) - 12d^2 + 3, 3\text{Hex}_{r-d} + 6\text{Hex}_{r+d} - 24d^2 + 8), (2(\text{Hex}_{r-d} + \text{Hex}_{r+d}) - 12d^2 + 3, 3\text{Hex}_{r-d} + 6\text{Hex}_{r+d} - 24d^2 + 8, 10\text{Hex}_{r-d} + 15\text{Hex}_{r+d} - 72d^2 + 20), \dots\}$ represents the half companion sequence of special Dio-tuples containing hex numbers of rank $r-d$ and $r+d$.

RESULTS AND DISCUSSIONS

3.1 Theorems on Non-extendibility

Theorem 1:

Extendibility of Dio-3 tuples formed by $\text{Hex}_r, \text{Hex}_{r+d}$ to quadruples is impossible for all $r \in \mathbb{W}, d \in \mathbb{Z}$ with $d \neq 0$.

Proof:

Consider η_1, η_2, η_3 with same property $D(3r^2d + 3rd^2 + 3rd + d^2 + d)$ which are used as in (1), (2) and (7) of Case 1(A).

Assume $\Phi_1 = u_1 + \eta_1 v_1, \Phi_2 = u_1 + \eta_2 v_1, \Phi_3 = u_1 + \eta_3 v_1$ for which any $g \in \mathbb{Z}^+$ satisfies the following equations.

$$\eta_1 g + 3r^2d + 3rd^2 + 3rd + d^2 + d = \Phi_1^2 \quad (29)$$

$$\eta_2 g + 3r^2d + 3rd^2 + 3rd + d^2 + d = \Phi_2^2 \quad (30)$$

$$\eta_3 g + 3r^2d + 3rd^2 + 3rd + d^2 + d = \Phi_3^2 \quad (31)$$

Removal of 'g' from (29) and (31) provides the initial solution $u_1 = 6r^2 + 6r + 3rd + 2d + 2, v_1 = 1$. This will lead to find $\Phi_1 = 9r^2 + 9r + 3rd + 2d + 3$. From (29), it is clear that

$$g = 3d^2 + 11d + 27r^2 + 27r + 18rd + 9 \quad (32)$$

Using all the known values in (30),

$$\begin{aligned} \Phi_1^2 &= 9d^4 - 72rd^3 + 24d^3 + 198r^2d^2 + 105rd^2 - 2d^2 + 216r^3d \\ &\quad + 171r^2d + 27rd - 15d + 81r^4 + 162r^3 + 135r^2 + 54r + 9 \end{aligned} \quad (33)$$

The triple $\{\eta_1, \eta_2, \eta_3\}$ are extended to quadruple if Φ_1^2 is a perfect square. Suppose that $d < r$, then taking $d = r - 1$ (where $r \neq 1$ as $d \neq 0$) in (33) gives $\Phi_1^2 = 576r^4 - 402r^3 + 175r^2 + 85r + 7$ which is not a perfect square for all $r \neq 1$. For the case $d > r$, substitution of $d = r + 1$ in (33) provides $\Phi_1^2 = 576r^4 + 1326r^3 + 1081r^2 + 347r + 25 \neq$ Perfect square for all $r \in \mathbb{W}$. Suppose $r = d \neq 0$, then (33) becomes gives $\Phi_1^2 = 576r^4 + 462r^3 + 168r^2 + 39r + 9 \neq$ perfect square for all $r \in \mathbb{W}, d \in \mathbb{Z} - \{0\}$. This proves the theorem.

Corollary 1

Dio-3 tuples formed by $\text{Hex}_r, \text{Hex}_{r+d}$ can be extended to quadruples for all $r \in \mathbb{W}, d \in \mathbb{Z}$ with $d = 0$.





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Theorem 2

For all $r \in W$, $d \in Z$ with $d \neq 0$, Dio-3 tuples produced by $\text{Hex}_{r-d}, \text{Hex}_{r+d}$ are not extendable to quadruples.

Proof:

The proof of this theorem is same as Theorem 1.

Corollary 2:

Dio-3 tuples formed by the hex numbers $\text{Hex}_{r-d}, \text{Hex}_{r+d}$ can be extended to quadruples for any $r \in W$, with $d=0$.

Theorem 3:

Special Dio-3 tuples generated by the hex numbers $\text{Hex}_{r-d}, \text{Hex}_{r+d}$ cannot be extendable to quadruples for all $r \in W$, $d \in Z$ with $d \neq 0$.

Proof:

Let $(\zeta_1, \zeta_2, \zeta_3)$ be same as in (15), (16) and (28) with same property $D(-15d^2+1)$.

Assume $\Delta_1 = c_1 + \zeta_1 b_1, \Delta_2 = c_1 + \zeta_2 b_1, \Delta_3 = c_1 + \zeta_3 b_1$ such that any $h \in Z^+$ satisfies the equations.

$$\zeta_1 h + \zeta_1 + h - 15d^2 + 1 = \Delta_1^2 \quad (34)$$

$$\zeta_2 h + \zeta_2 + h - 15d^2 + 1 = \Delta_2^2 \quad (35)$$

$$\zeta_3 h + \zeta_3 + h - 15d^2 + 1 = \Delta_3^2 \quad (36)$$

The value of c_1^2 can be obtained on elimination of 'h' from (34) and (36)

$$c_1^2 = -15d^2 + (\zeta_1 + 1)(\zeta_3 + 1)b_1^2$$

The following initial solution can be depicted from the above equation by the substitution of (1) and (22)

$$c_1 = 6r^2 + 6r - 6rd - 3d + 4, b_1 = 1$$

Utilizing the above solution, one may get $\Delta_1 = 9r^2 + 9r - 12rd - 6d + 3d^2 + 6$. Replacement of all the obtained values in (34) results in finding 'h' as

$$h = 3r^2 - 18rd - 9d + 27r^2 + 27r + 17 \quad (37)$$

From (35),

$$\Delta_2^2 = 81r^4 + 162r^3 - 199r^2d^2 + 108r^3d - 18d^3 + 162r^2d^2 + 189r^2 - 36rd^3 - 18rd^2 + 108r + 9d^4 + 126rd + 81r^2d^2 + 18d^2 + 36d + 36 \quad (38)$$

Now, the special Dio triple $(\zeta_1, \zeta_2, \zeta_3)$ can be extended to quadruple only if Δ_2^2 is a perfect square. In order to verify, the following cases are taken into account.

Case (i): $d < r$. If $d = r - 1$ (where $r \neq 1$ as $d \neq 0$), then (38) becomes $\Delta_2^2 = 225r^4 + 126r^3 + 270r^2 - 90r + 45 \neq$ perfect square.

Case (ii): $d > r$. Suppose $d = r + 1$, (38) turns to $\Delta_2^2 = 225r^4 + 450r^3 + 414r^2 + 234r + 81 \neq$ perfect square.

Case (ii): $d = r \neq 0$. The value of Δ_2^2 in (38) leads to $\Delta_2^2 = 225r^4 + 228r^3 + 333r^2 + 144r + 36 \neq$ perfect square.

\therefore A special Dio-triplet formed by $\text{Hex}_{r-d}, \text{Hex}_{r+d}$ are not extendable to quadruples for all non-negative integer values of r and non-zero integer d .

Corollary 3

Special Dio-triple $(\zeta_1, \zeta_2, \zeta_3)$ can be extended to quadruples for any $r \in W$ with $d=0$.

Theorem 4

Let (η_1, η_2, η_3) be a special Dio-3 tuple generated by the hex numbers $\text{Hex}_r, \text{Hex}_{r+d}$. For all $r \in W$, $d \in Z$ with $d \neq 0$, (η_1, η_2, η_3) cannot be extended to quadruple and it is extendable for $d=0$.

Proof: The Proof of this theorem is similar to Theorem 3.

3.2 Pictorial Comparison



CONCLUSION

The generalized version of half companion sequence of Dio-3 tuples and special Dio-3 tuples are found by using Hex numbers of ranks $r, r+d$ and $r-d, r+d$. Non-extendibility to quadruples is proved for all values of $r \in \mathbb{W}, d \in \mathbb{Z} - \{0\}$. Also, the behaviour of the scattered plot of the Dio-triples and special Dio-triples are compared and one can analyze that for the ranks $r, r+d$, the path traced by scattered plot of the Dio-triples is exactly same as Special Dio-triples. Similarly, for the ranks $r-d, r+d$, the path traced is same for Dio-3 tuples and special Dio-3 tuples.

Conflict of Interest

The authors declare no conflict of interest in this article.

Data Availability

No Data available.

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Table.1: Few examples of half companion sequences of Dio-3 tuples for $\text{Hex}_r, \text{Hex}_{r+d}$

d	r	(η_1, η_2, η_3)	(η_2, η_3, η_4)	(η_3, η_4, η_5)	$D(3r^2d+3rd^2+3rd+d^2+d)$
1	1	(7,19,50)	(19,50,131)	(50,131,343)	D(11)
	2	(19,37,110)	(37,110,275)	(110,275,733)	D(26)
2	1	(7,37,78)	(37,78,223)	(78,223,565)	D(30)
	2	(19,61,150)	(61,150,403)	(150,403,1045)	D(66)

Table.2: Few examples of half companion sequences of Dio-3 tuples for $\text{Hex}_{r-d}, \text{Hex}_{r+d}$

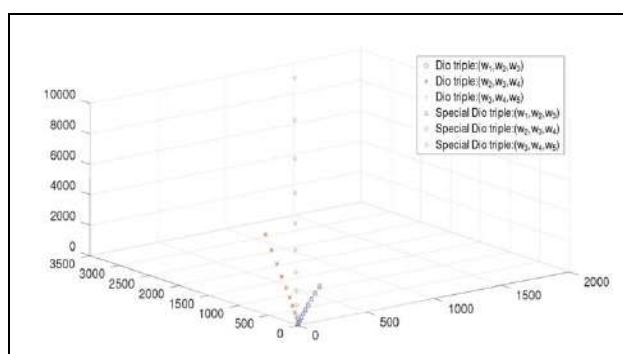
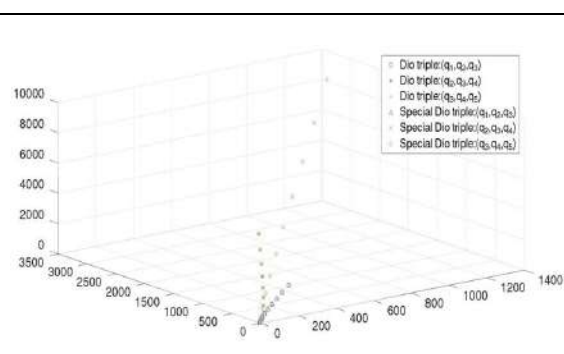
d	r	$(\zeta_1, \zeta_2, \zeta_3)$	$(\zeta_2, \zeta_3, \zeta_4)$	$(\zeta_3, \zeta_4, \zeta_5)$	$D(-3d^2)$
1	1	(1,19,28)	(19,28,93)	(28,93,223)	D(-3)
	2	(7,37,76)	(37,76,219)	(76,219,553)	D(-3)
2	1	(1,37,28)	(37,28,129)	(28,129,227)	D(-12)
	2	(1,61,76)	(61,76,273)	(76,273,637)	D(-12)

Table.3: Some illustrations of half companion sequence of special Dio-triples involving $\text{Hex}_r, \text{Hex}_{r+d}$

d	r	$(\eta_1, \eta_2, \eta_3')$	$(\eta_2, \eta_3', \eta_4')$	$(\eta_3', \eta_4', \eta_5')$	$D(1-2d^2+3r^2d+3rd^2+3rd+2d)$
1	1	(7,19,53)	(19,53,139)	(53,139,367)	D(10)
	2	(19,37,113)	(37,113,283)	(113,283,757)	D(25)
2	1	(7,37,81)	(37,81,231)	(81,231,589)	D(21)
	2	(19,61,153)	(61,153,411)	(153,411,1069)	D(57)

Table.4: Few illustrations of half companion sequence of special Dio-triples involving $\text{Hex}_{r-d}, \text{Hex}_{r+d}$

d	r	$(\zeta_1, \zeta_2, \zeta_3')$	$(\zeta_2, \zeta_3', \zeta_4')$	$(\zeta_3', \zeta_4', \zeta_5')$	$D(-15d^2+1)$
1	1	(1,19,31)	(19,31,101)	(31,101,247)	D(-14)
	2	(7,37,79)	(37,79,227)	(79,227,577)	D(-14)
2	1	(1,37,31)	(37,31,137)	(31,137,301)	D(-59)
	2	(1,61,79)	(61,79,281)	(79,281,661)	D(-59)

Figure.1: Comparison of Dio and Special Dio-triples generated by $\text{Hex}_r, \text{Hex}_{r+1}$ Figure.2: Comparison of Dio and Special Dio-triples generated by $\text{Hex}_{r-1}, \text{Hex}_{r+1}$ 



Anxiety, Practice Modification, Economic Impact with Quality of Life among Dentists of Karnataka using WHOQOL-BREF Instrument Post COVID Outbreak

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ABSTRACT

COVID 19 reaction responses challenged the health professions and systems around the globe. The role of the dental professionals in preventing the transmission and responding to its long-term impacts on dentistry is critically important. Hence the study was conducted post COVID outbreak. A cross sectional, questionnaire study was conducted among dentists of Karnataka using WHOQOL-BREF instrument. 750 dentists participated in the study mentioned that they had an anxiety of being infected with COVID – 19 by one or the other way during the outbreak & all most all the dentists mentioned that they faced the increased economic burden to update / modify the clinic for their & patients protection. 92% were dissatisfied by themselves & 24% expressed even personal relationships were affected& their quality of life was compromised. Outlining the immediate impact that the Covid-19 outbreak had on dental healthcare professionals looks heavier at some points on the profession but currently dentists have adapted to the changes and balancing the economic crisis.

Keywords: Covid-19 outbreak, Dental professionals, Impact on dentistry.





INTRODUCTION

Since the emergence of the novel coronavirus disease (COVID19) in Wuhan, China, all aspects of life have been influenced worldwide. The COVID-19 pandemic has spread in an exponential manner affecting millions of people worldwide and causing hundreds of thousands of deaths.[1] Many countries have shut down their teaching institutes, industries, sport activities, social gatherings, public events, and airports. Drastic measures such as individual self-quarantine and social distancing rules have been introduced in an attempt to control the spread of the infection.[2] As health care workers on the front line during the coronavirus (COVID-19) pandemic, dental practitioners are amongst those at risk due to their close contact with potentially infected individuals.[3,4] Droplets and aerosols that are generated during dental procedures by such as high speed handpieces, air-water syringes, and ultrasonic scaling produce a contaminated pathogenic environment during treatment of an infected person. Therefore, the risk of infection transmission within the dental team cannot be controlled through the standard protective measures of daily dental practice.[5] This categorization as high-risk professionals increased fear within the dental community. Regarding the rapid spread of the infection, WHO, Dental council of India announced specific guidelines to be implemented by dentists while during treating urgent and emergency cases, otherwise they stipulated the dental offices to be kept closed during the outbreak. This insisted for modification in clinical setting leading to increase demand for expensive aerosol controlling equipment such as the high efficiency particulate arrestor (HEPA).[1] The expense of these precautionary measures and limitations in the treatment of patients may have had serious economic impact on the dentistry field.[6-9] There are no studies which have assessed the levels of anxiety among dentists after the COVID-19 outbreak, their practice modifications to prevent its spread, or the financial impact on their current practice along with their quality of life. Therefore, the aim of the current study was to use a specially designed online-based questionnaire to assess the impact of the COVID-19 outbreak on dentists in terms of their anxiety, awareness and practice modification, and the financial implications along with QOL for their dental practice.

Aim and Objectives of Study

Aim

To assess anxiety, practice modification, economic impact with quality of life among dentists of Karnataka using WHOQOL-BREF instrument post COVID outbreak.

Objectives

- To assess the anxiety, awareness & practice modification and financial impact among dentists of Karnataka.
- To assess the QOL by using WHOQOL-BREF among dentists of Karnataka

MATERIALS AND METHODS

Study Design: Descriptive cross sectional online questionnaire study.

Study Setting: Dentists of Karnataka from Karnataka state dental registry.

Study Duration: 6 months

Source of Data: Data will be collected from the dentists through online.

Materials: Self administered Questionnaire & WHOQOL – BREF

Methods of Collection of Data

Google forms was created to include all the questions & sent to registered dentists from KSDC registry using social media, emails and only completed forms were included in the final analysis. All incomplete forms and those returned outside the required timeframe were excluded.



**Sample Size**

The total number of registered dentists, as officially found in KSDC registry on 26/08/2022, was 26,000. Sample size was determined according to the following formulas:

Sample size = (distribution of 50%)/[(margin of error%/ confidence level score)²]

Confidence level = 1.96 (for confidence level of 95%), margin of error = 0.05.

True sample = (sample size × population)/ (sample size + population – 1)

The calculated sample size was equal to 746 which were rounded equal to 750 dentists. Accordingly, the questionnaire link was sent via emails & social media.

Methodology

The questionnaire used for this study was composed of demographic/practice-related, closed end, and Likert five-point scale questions. The questionnaire has two parts, Part 1 contains 24 questions & these questions were divided into four sections: Section 1 - designed to collect demographic/practice-related variables of the respondents. Section 2, questions 1 to 6 - intended to assess the anxiety among dentists deriving from the COVID-19 infection. Section 3, questions 7 to 15 - designed to evaluate the practice modification about the precautions and infection-control measures for COVID-19 infection. Section 4, questions 16 to 24 - consisted of questions that explored the economic impact of COVID-19 on dental practice. Part 2 contains WHOQOL-BREF questionnaire having 20 questions which addresses four domains of QOL which are physical, psychological, social relationships, and environmental areas. The physical domain includes pain and discomfort facet, and it assesses the physical condition of a person and how it interferes with his/her daily life activities. The psychological domain examines how often a person experiences positive and negative perceptions and what impact they have on a person's daily functioning. The social domain addresses the personal relationships and social support a person has and their impact on his/her life. The environmental domain includes physical safety facet which examines if a person feels secure from any physical harms.

Statistical Analysis

Data was analyzed using the Statistical Package for Social Sciences (SPSS) version 22.0 statistical software. Descriptive statistics, Kappa statistics, Chi-square and ANOVA were used. The statistical significance was set at 5% level of significance ($p < 0.05$).

RESULT

Demographic distribution in the study shows gender & education wise distribution of study participants which was almost 1:1. General practitioners & specialists were almost equally distributed in the study. More than 90% of the participants are clinicians & all of them were private practitioners. (Table 1) Table 2 depicts anxiety, practice modification & economic impact on dentists during COVID outbreak. All participant dentists mentioned that they had an anxiety of being infected with COVID – 19 by a patient or co-worker & they were afraid to provide any treatment especially if a patient is coughing or suspected to be infected. They even mentioned to be anxious to talk in close proximity with patients as they may carry the infection back to family. This anxiousness was reported to be more when they heard about their co-worker or colleague being infected but all were updated with the WHO guidelines for cross-infection control for COVID – 19. All most all dentists mentioned that they asked every patient regarding the COVID history and checked temperature before treatment, increased the infection control procedure during the pandemic. All most all dentists got tested for COVID – 19 as a precautionary measure & knew whom to contact if they come across the infection. All routinely followed washing hands with soap & water /use of sanitizer before & after treatment of every patient which is reported to be continued till today. 78% of the dentists mentioned that their practice schedule was changed to make it safer for them & patient during the pandemic but still 81% of them reported that there was a drop in 25% of the patients. At the same time 62% of the dentists reported that they cancelled appointments for non – urgent cases as a part of precaution protocol. 80% of them mentioned they reduced staff numbers in their clinic & even the working days were reduced to 100% especially during the outbreak. All this



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lead to severe economic crisis for a dentist during the period but there was no financial compensation by either Government or Non-Government agencies. All most all the dentists faced the increased economic burden to update / modify the clinic for their & patients protection at the same time patient in flow was also reduced leading to difficulty to sustain during the phase. Table 3 depicts impact of COVID outbreak on quality of life of dentists which was measured using WHOQOL-BREF questionnaire. 49% of them answered their quality of life was bad, 92% were dissatisfied by themselves & 24% expressed even personal relationships were affected. 74% of them were neutral to mention whether they were satisfied by their health & to what extent the physical pain prevented them from what they need to do. 68% were dissatisfied by the conditions of their living place & about 95% of them had faced negative feelings such as bad mood, anxiety & depression at different frequencies but 62% of dentists mentioned they got support from their friends.

DISCUSSION

In the current study, the participant dentists mentioned the COVID-19 pandemic changed their career perspectives and almost all feared of getting exposure to COVID-19 while performing their profession this was similar to post graduate students perception from Turkey.[2] Acute anxiety levels of the students were recorded mild to highest which was similar to all current study participants.[2] A study conducted post COVID among Iraqi dentists showed more than 80% of participants reported anxiety of catching COVID-19 similar to the present study. The recorded anxiety level was higher amongst younger dentists and females which was common to both genders in current study. Awareness and practice levels among these dentists of precautions and infection-control measures associated with COVID-19 (100%) was found to be high similar to study conducted by Mahdee AF *et al.*[3] With respect to the economic impact, about 75% of practitioners, regardless of demographical variables, reported that their income had declined by about 50% similar to Iraqi dentists.[3] A comprehensive, cross-sectional survey conducted among 875 Polish dental practitioners showed 71.2% of dentists who responded to the questionnaire decided to suspend their clinical practice similar to dentists in the current study.[4] This may be due to respondents' perceptions of the risk of COVID-19 contraction and a general feeling of anxiety and uncertainty regarding the COVID-19 situation.[4] The quality of life (QOL) of dental professionals rated by participated dentists as good was only 19% which was more in the Eastern Province of Saudi Arabia (75%) which may be due to the support system present there. The social relationship domain was better similar to Nabras A *et al.*[1] The qualifications and years since graduation were important determinants of QOL among dental professionals which was noted in the current study as well. The quality of life (QoL) and limitations were experienced due to pandemic management-related measures during the first lockdown after the coronavirus outbreak. A study among Slovakian dentists showed worsening of QoL happened because of information overload and several pandemic-related limitations. The increase in economic burden can be due to reduced patient flow, restricted timings, infection risks in the work environment, obligatory safety measures, lack of staff and client concerns. Overall pandemic management has led to a considerable worsening of dentists' QOL in Iraq³ and Slovak dentists⁵ similar to dentists of Karnataka.

CONCLUSION

The healthcare providers are susceptible to occupational risks that can affect their quality of work through exposure to chemicals, radiations, physical, and psychosocial hazards. Therefore, the World Health Organization (WHO) selected healthcare providers as a priority group for the improvement in their workplace health and safety in the work plan 2009–2012. But, COVID - 19 laid many challenges for a dentist compromising their quality of life with increased economic burden. Hence, high quality dental care and patient satisfaction in turn requires physical and mental efforts of the dentist, and this makes QOL a vital concept in today's dental practice.





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Table.1: Demographic Details

Patient Demographic Details			
1	Gender wise Distribution		
	Male – 53.3%	Female – 46.6%	
2	Education		
	BDS – 45.3%	MDS – 54.6%	
3	Qualification		
	General practitioners – 45.3%	Specialists – 48%	Consultants – 6.6%
4	Nature of work		
	Clinic – 81.3%	College/Hospital – 3.06%	Both – 15.6%
5	Sector		
	Private – 100%	Government - 0	

Table.2: Anxiety, practice modification & economic impact of dentists during COVID outbreak

SI no	Questions	Response	
		Yes	No
1	Anxious of being infected by patient or Co-worker	100%	0
2	Afraid to treat patients	100%	0
3	Anxious to talk to patients in close proximity	100%	0
4	Afraid of carrying infection back to family	100%	0
5	Anxious when coworker/colleague got infected	100%	0





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6	Updated with WHO guidelines	78%	22%
7	Take history of COVID 19	100%	0
8	Check body temperature before procedure for every patient	90%	10%
9	Wash hands with soap & water/use sanitizer after each patient	100%	0
10	Increased infection control procedures in clinic	100%	0
11	Practice schedule changed	77%	23%
12	Got tested for COVID – 19 as precautionary measure	100%	0
13	Know whom to contact if you come across suspected patient	100%	0

Table.3: Quality of life of dentists during COVID outbreak

Sl no	Questions	Responses				
		Highly satisfied	Satisfied	Neutral	Dissatisfied	Highly dissatisfied
1	Are you satisfied with your health?	0	3	74	23	0
2	What extent physical pain prevented you from doing what you need to do?	0	31%	64%	5%	0
3	How satisfied are you with yourself?	0	2%	93%	5%	0
4	How satisfied are you with personal relationships?	0	12%	64%	24%	0
5	How satisfied are you with the conditions of your living?	5%	27%	68%	5%	0
6	How satisfied are you with the support from your friends?	14%	62%	24%	0	0
7	How often do you have negative feelings?	Very often – 16%	Often – 55%	Neutral – 12%	Sometimes – 17%	Not at all - 0
8	How do you rate your QOL?	Very good - 0	Good – 19%	Average – 23%	Bad – 49%	Very bad – 9%





Addressing CO Poisoning in Formic Acid Oxidation: Pt-Ru based Electro Catalysts for Fuel Cells

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ABSTRACT

The oxidation of formic acid plays a pivotal role in advancing fuel cell technology, with Pt recognized as a potent electro catalyst for this reaction. However the persistent issue of CO poisoning on the Pt surface during the reaction has driven significant research efforts.CO adsorption on Pt catalyst hampers catalytic activity and efficiency. In this presentation, we delve into the challenge of CO poisoning and the strategies employed to mitigate its effects. The issue of CO poisoning on the catalyst surface can be reduced by incorporating a second metal, such as Ru, Sn, Pd, or Mo, alongside Pt. Among various bimetallic catalysts, Pt–Ru stands out as particularly effective in enhancing the kinetics of the formic acid oxidation reaction. This is largely because Ru promotes the generation of oxygen-containing species at lower potentials compared to Pt, which subsequently assists in oxidizing CO molecules on nearby sites, converting them into CO₂. To minimize the use of Pt, it is advisable to disperse it on an appropriate support in the form of nanoparticles. This dispersion increases the effective surface area of the Pt catalyst, thereby enhancing the efficiency of the methanol oxidation process. Conducting polymers can act as excellent scaffolds for the high dispersion and anchoring of metal nanoparticles, providing a large surface area and offering protection against catalyst fouling. Investigation of the electrocatalytic properties of the



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PoPD-Pt-Runanocomposite electrode for formic acid oxidation using linear sweep and cyclic voltammetry. The Pt-Ru ion concentration ratios in the electrodeposition bath were varied as 1:0.25, 1:0.5, 1:1, 1:2, and 1:4. Scanning electron microscopy (SEM) results were used to determine the shape and particle size of the nanocomposites. The PoPD-Pt-Ru (1:1) film has the highest current among the PoPD-Pt-Runanocomposites that have been examined. Using the peak current information from the cyclic voltammetry the PoPD-Pt-Ru (1:1) nanocomposite shows the lowest level of surface poisoning. However, the reverse peak current magnitude, or the forward-to-reverse peak current ratio (I_f/I_r), serves as an indicator of the catalyst's performance. A higher (I_f/I_r) value corresponds to better catalytic activity. The stability and polarization statistics support the conclusions.

Keywords: Poly(o-phenylenediamine) , Electrocatalyst, Pt-Ru nanoparticles, Formic acid oxidation

INTRODUCTION

The continuous exploration of innovative electrocatalysts for the oxidation of formic acid remains of significant interest, primarily due to their vital role in enhancing fuel cell performance and advancing sustainable energy technologies. Among various electrocatalysts, Platinum (Pt) has been identified among the most effective catalysts for formic acid oxidation. Carbon monoxide (CO), an intermediate produced during the reaction, poisons the Platinum (Pt) surface, posing a serious threat to the formic acid oxidation process. The effectiveness of the catalyst is dramatically decreased by CO adsorption on Pt sites. To mitigate this issue, the incorporation of a secondary metal, such as ruthenium (Ru), tin (Sn), palladium (Pd), or molybdenum (Mo), into Pt-based catalysts has proven to be effective. Bimetallic catalysts, particularly Pt-Ru exhibits significant effectiveness in enhancing the kinetics of formic acid oxidation. This enhancement is attributed to Ru's ability to produce oxygen-containing species at lower potentials than Pt. These oxygen species aid in the oxidation of CO molecules on adjacent Pt sites, converting them into CO_2 , thereby mitigating surface poisoning. To enhance the execution of the catalyst, a strategy has been proposed to reduce the Pt content by dispersing it as nanoparticles on an appropriate support material. This dispersion strategy not only reduces the quantity of expensive Pt required but also increases the active surface area for catalysis, playing a crucial role in determining the efficiency of the reaction and improving the overall efficiency of the process. Conducting polymers, such as poly(o-phenylenediamine) (PoPD), are promising scaffolds for dispersing and anchoring metal nanoparticles. These polymers ensure continuous catalytic activity by offering a high surface area and shielding the catalyst from fouling.

Using cyclic voltammetry and linear sweep techniques, PoPD-Pt-Runanocomposite electrodes have undergone the subject of electrochemical research for the oxidation of formic acid. The ratio of Pt to Ru ions in the electrodeposition bath has been systematically varied (1:0.25, 1:0.5, 1:1, 1:2, and 1:4) to examine how the composition affects catalytic activity. The scanning electron microscopy (SEM) data reveal the morphology and particle diameter of the resulting nanocomposites. Among the various PoPD-Pt-Ru compositions, the PoPD-Pt-Ru (1:1) nanocomposite exhibits the highest forward peak current, indicating superior catalytic activity. The ratio of forward to reverse peak current (I_f/I_r) serves as a metric for evaluating catalyst performance, with higher values reflecting reduced surface poisoning and improved catalytic efficiency. Polarization and stability studies validate the PoPD-Pt-Ru (1:1) nanocomposite's superior capacity to minimize surface poisoning, as seen by the cyclic voltammetry data. In addition to its role in enhancing the kinetics of formic acid oxidation, Ru also influences the structural and electronic properties of the Pt catalyst. Furthermore to preventing CO poisoning, the contact between Pt and Ru fosters improved electron transport and formic acid adherence on the catalyst surface. Moreover, the utilization of conducting polymers as supports can significantly improve the stability and durability of the catalyst, making it more resistant to degradation during long-term operation. As Well As consequently, the efficiency of the electrocatalysts for HCOOH oxidation can





be greatly improved by adjusting the composition of Pt and Ru and using conducting polymers like PoPD as supports, opening the door to more effective fuel cell technologies.

Experimental section

After recrystallization from hot water *o*-phenylenediamine (s.d. fine) was employed Chloroplatinic acid ($\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$), sodium sulfate, ruthenium chloride ($\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$) H_2SO_4 (s.d fine) of analar grade were utilized. The EG&G, PAR Model 263A Potentiostat/Galvanostat was used to conduct the electrochemical tests. Three electrode spaces were provided by a one-compartment cell. After polishing with fine-alumina, a glassy carbon electrode with an area of 0.07 cm^2 (Electro chemical analyser, USA) was employed, and it was sonicated in water for several minutes. The reference and counter electrodes consisted of a saturated calomel electrode (SCE) and a platinum foil (1 cm^2), respectively. Every electrochemical experiment was conducted in a N_2 environment. By cycling the potential at 50 mV s^{-1} between -250 and $1,050 \text{ mV}$ versus SCE, PoPD was electro deposited on glassy carbon electrode (GCE) from a nitrogen-purged aqueous electrolyte solution comprising $5 \times 10^{-2} \text{ M}$ monomer and $0.2 \text{ M Na}_2\text{SO}_4$ at pH 1. In every experiment, a thin film created using ten deposition cycles was employed. The following protocols are utilized to deposit Pt and Pt-Ru nanoparticles on PoPD film. The electro reduction $\text{H}_2\text{PtCl}_6 \cdot 2\text{H}_2\text{O}$ (2.4 mM) in $0.2 \text{ M Na}_2\text{SO}_4$ at pH 1 was used to load Platinum (Pt) on the PoPD film. The electrode that is produced is called PoPD -Pt. After being dissolved in $0.2 \text{ M Na}_2\text{SO}_4$, a solution comprising $2.4 \text{ mM H}_2\text{PtCl}_6 \cdot 2\text{H}_2\text{O}$ and $x\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$ ($0.6 \text{ mM} < x \leq 6 \text{ mM}$) was used to electroplate the Pt–Ru nanoparticles on the PoPD. The Pt to Ru ion concentration ratio is indicated in parentheses for each of the following designations: (1:0.25), (1:0.5), (1:1), (1:2), and (1:4). Using a potentiostatic technique, Pt and Pt-Ru nanoparticles were electrodeposited at a selected potential of $+250 \text{ mV}$. Assuming 100% coulombic efficiency and considering Pt as the sole metal deposited, a charge of 200 mC cm^{-2} was employed, which corresponds to the deposition of $100 \mu\text{g cm}^{-2}$ of Pt. A scanning electron microscopy (SEM) (Shimadzu, 8400S) was utilized to ascertain the structure of PoPD film and its metal nanocomposites.

RESULTS AND DISCUSSION

Direct formic acid fuel cells represent a potentially transformative energy source for portable applications, primarily owing to the convenience of fuel transport and processing [1,2]. Even though adsorbed CO, an intermediate created during the electrochemical oxidation of formic acid, poisons Pt, it is still the favored electrocatalyst for this process. Ru's ability to convert CO into CO_2 can minimize CO adsorption at the Platinum (Pt) electrode surface [3]. This study compares the PoPD-Pt-Ru nanocomposite's electrocatalytic efficacy for formic acid oxidation to that of the PoPD-Pt nanocomposite.

The Electrocatalytic Properties of PoPD-Pt-Ru Nanocomposites: Synthesis of PoPD

PoPD's electrochemical synthesis and several technique-based characterization have been extensively documented in the literature [1, 2–6]. A small modification of the method is used in this study to obtain PoPD film on a Pt substrate [1]. The electrolyte is composed of $0.2 \text{ M Na}_2\text{SO}_4$ and $50 \text{ mM o-phenylenediamine}$, which has been brought to pH 1 by adding concentrated H_2SO_4 . By cycling the potential between -250 and $+1050 \text{ mV}$ at 50 mV s^{-1} for ten cycles, the PoPD is deposited on a glassy carbon electrode (GCE) disc (0.0314 cm^2) (Fig. 1.1). Monomer oxidation is shown by the big peak at $+620 \text{ mV}$ in the first cycle (inset Fig. 1.1). The creation of the PoPD film on the GCE surface can be determined by the emergence of a new redox pair at lower potentials with rising current amplitude during cycling.

The FT-IR spectrum of the PoPD polymer sample that was synthesized electrochemically is shown in Figure 1.2. As indicated in Table 1.1, The distinct bands are attributed to specific stretching and bending vibrations, with the data showing exceptional alignment with those reported in the literature by other authors for PoPD. [4, 5, 6, 7]. The appearance of a band at 840 cm^{-1} , which is suggestive of a 1,2,4,5-tetra-substituted benzene ring, is the notable finding. Scheme 1 depicts the ladder structure built up of phenazine rings that has been assigned to PoPD.





Preparation of PoPD-Pt-RuNanocomposite

The following procedures outline the methods for depositing Pt and Pt-Ru nanoparticles on PoPD film. At the PoPD-modified GCE (PoPD/GCE), Pt is loaded via electroreduction of 2.4 mM $\text{H}_2\text{PtCl}_6 \cdot 2\text{H}_2\text{O}$ in 0.2 M Na_2SO_4 at pH 1. Pt-Ru nanoparticles are electrodeposited on the PoPD/GCE using a solution containing $\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$ ($0.6 \text{ mM} < x \leq 9.6 \text{ mM}$) and 2.4 mM $\text{H}_2\text{PtCl}_6 \cdot 2\text{H}_2\text{O}$ in 0.2 M Na_2SO_4 . A potentiostatic method is applied for the electrodeposition of Pt and Pt-Ru nanoparticles, with a preferred deposition potential of +250 mV. number can be seen by the numbers in the visual representation. First cycle shown in the inset. A charge of 200 mC cm^{-2} is applied, which, assuming 100% Coulombic efficiency and Pt as the only metal deposited, results in the deposition of $100 \mu\text{g cm}^{-2}$ of Pt. The Pt-to-Ru ion concentration ratio is indicated in parentheses for each of the nanocomposite electrodes, named as PoPD-Pt, PoPD-Pt-Ru (1:0.25), PoPD-Pt-Ru (1:0.5), PoPD-Pt-Ru (1:1), PoPD-Pt-Ru (1:2), and PoPD-Pt-Ru (1:4). The *i-t* curves for the potentiostatic deposition of Pt and Pt-Ru nanoparticles on PoPD/GCE, leveraging distinct concentration ratios of $\text{H}_2\text{P}_2\text{I}_6 \cdot 2\text{H}_2\text{O}$ and $\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$, are shown in Figure 13. The *i-t* curve obtained in the $\text{H}_2\text{P}_2\text{I}_6 \cdot 2\text{H}_2\text{O}$ solution distinct drastically from those obtained in solutions containing both $\text{H}_2\text{P}_2\text{I}_6 \cdot 2\text{H}_2\text{O}$ and $\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$ for a deposition charge of 200 mC cm^{-2} in that, for Pt-Ru deposition, the duration needed to pass a total charge varies according to the concentration of $\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$ in the electrolyte, with approximately 1000 seconds required for Pt-only deposition. While the deposition sequences exhibited minor differences at Pt-to-Ru ion concentration ratios up to 1:1, a significant enhancement in steady-state currents was observed at concentration ratios of 1:2 and 1:4, suggesting that the deposition of Ru surpasses that of Pt.

Characterization of PoPD-Pt-RuNanocomposite

Figure 1.4 At a scan rate of 50 mV s^{-1} in 0.2 M Na_2SO_4 at pH 1, the cyclic voltammograms of the PoPD-Pt and PoPD-Pt-Ru nanocomposites are presented. Notably, the voltammogram of the PoPD-Pt-Ru (1:0) nanocomposite (Fig. 1.4 A) reveals distinctive peaks in the hydrogen region. The deposition of Pt particles on the layer of the PoPD film is demonstrated by distinct characteristics observed across several potential ranges: from -250 to +150 mV, within the double-layer charging region (+150 to +375 mV), and in the oxygen zone (+375 to +800 mV) [8]. These characteristics provide clear evidence of Pt particle presence on the PoPD film surface. In the nanocomposites with higher concentrations of ruthenium chloride (PoPD-Pt-Ru (1:1), PoPD-Pt-Ru (1:2), and PoPD-Pt-Ru (1:4)), the hydrogen adsorption-desorption peaks remain pronounced; however, the peak at -250 mV becomes indistinguishable. Moreover, increasing the Ru concentration causes a negative shift in the oxide reduction potential and broadens the double-layer charging regions. This behavior is likely a result of the formation of Ru-OH species on the catalyst surface, due to Ru's hydrophilic properties. These findings are consistent with earlier studies on Pt-Ru alloy electrodes. [9–12].

The Electrocatalytic Oxidation of Formic Acid: Insights and Advances

The electrocatalytic performance of PoPD-Pt and bimetallic PoPD-Pt-Ru nanocomposites in the formic acid oxidation was assessed using a 0.5 M formic acid solution in 0.2 M Na_2SO_4 at pH 1, utilizing cyclic voltammetry and chronoamperometry. Figure 1.5 A illustrates the cyclic voltammogram for the oxidation of formic acid on the PoPD-Pt electrode using a scan rate of 5 mV s^{-1} , revealing distinct peaks that correspond to formic acid oxidation in both the forward and reverse scans. Notably, two anodic peaks appear at +295 mV and +570 mV during the forward scan, which align with the characteristics associated with formic acid oxidation on Pt electrodes [13]. The initial peak at -290 mV signifies the direct oxidation pathway of formic acid to CO_2 , while the peak at +570 mV indicates the oxidation of CO species adsorbed on the Platinum (Pt) surface due to the non-faradaic dissociation of formic acid, representing the indirect pathway. During the reverse sweep, a crest at +323 mV further corroborates the direct oxidation of formic acid without CO poisoning across the catalyst surface. The tolerance of the catalyst to CO poisoning can be quantified by calculating the I_f/I_r ratio, which compares the crest current of the first forward peak (I_f) with that of the reverse peak (I_r). For the PoPD-Pt electrode, an I_f/I_r ratio of 0.2 indicates that CO adsorption initially poisons 80% of the catalytic surface. In contrast, the PoPD-Pt-Ru (1:0.25) electrode exhibits a markedly different voltammetric response, as depicted in Figure 1.5 B. Here, the anodic and cathodic scans reveal a single oxidation peak current for formic acid oxidation, with a cathodic peak potential of +544 mV, shifted relative to that of the PoPD-Pt electrode."





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This clarifies the comparison between the peak potentials of formic acid oxidation and the PoPD-Pt electrode. The lack of a second peak at a more positive potential indicates diminished CO formation or adsorption during the electro-oxidation process. Moreover, the close similarity between the oxidation and reduction peak currents suggests a well-balanced electrochemical reaction, evidenced by an I_f/I_r ratio close to 0.9, reinforces the exceptional tolerance of this catalyst to CO adsorption, this suggests that the primary contribution to the voltammetric current arises from the direct oxidation of formic acid to CO_2 . The PoPD-Pt-Ru (1:1) film exhibits the greatest electrochemical response among the PoPD-Pt-Ru nanocomposites examined (Fig 1.6). In contrast, catalyst performance can be assessed by analyzing the magnitude of the reduction peak current or the ratio between the oxidation and reduction peak currents (I_f/I_r). A higher I_f/I_r ratio reflects improved catalytic activity. Based on cyclic voltammetry peak current data, the PoPD-Pt-Ru (1:1) nanocomposite shows the least surface poisoning, indicating superior catalytic efficiency. (Table 1.2).

Kinetic analysis

Kinetic analysis for formic acid oxidation made by Butler Volmer and Tafel equations. A brief introduction of both of these equations is given below.

Exchange current density (i_0)

Butler [14] originally laid out the notion of exchange current density in electrode kinetics. As early as 1938, Bowden and Agar listed the exchange current density in a review [15]. Papers by Eyring, Glasstone and Laidler [16], Rojter, Juza and Poluyn [17], and Dolin and Ershler [18] all cited exchange current in the early years. Dolin and Ershler [18] also invented the phrase "exchange current." The choice of the name 'exchange current' was very apt because there is an exchange between the electrode and the solution which can easily be demonstrated for a metal-amalgam and metal-ion electrode by labeling the metal in one other the phases by a radio tracer. When the amalgam contacts the metal ion solution, the tracer rapidly transitions to the other phase, assuming the exchange current is sufficiently high, despite the absence of any net current at the electrode/solution interface. The exchange current density is calculated by multiplying an electrochemical specific rate constant with a concentration term. Consequently, while i_0 is helpful in comparing the catalytic activity of various electrode materials (electrocatalyst) for a particular reaction, it will not aid in the mechanism determination. To empirically determine the exchange current density, the linear portion of the $\eta/\log i$ plot is extrapolated to the reversible potential, where η equals zero. Additionally, the isotope exchange rate can be employed for a direct measurement of i_{0i_0i0} ; however, due to the labor-intensive nature of this method, it is seldom utilized.

Tafel slope (b)

Tafel proposed a fundamental correlation between overpotential (η) and current density.

[19] in 1905 on the basis of experimental investigations on the hydrogen evolution reaction. This is known as Tafel equation

$$\eta = a - b \log i \quad (1.1)$$

The overpotential (η) is a key concept in electrochemistry, Defining the departure from equilibrium states in an electrochemical reaction. It is calculated as the difference between the actual potential (E) observed when a current passes through the electrode-electrolyte interface and the reversible potential (E_r), which is the theoretical potential under equilibrium when no current flows. This deviation arises due to various kinetic factors, such as activation barriers and concentration gradients that impede the ideal, reversible reaction pathway. In practical systems, overpotential is critical in determining the efficiency and rate of electrochemical processes, with higher overpotentials indicating greater energy losses.

$$\eta = E - E_r \quad (1.2)$$

The variable 'b' is known as Tafel slope

$$b = \pm \left(\frac{\delta \eta}{\delta \log i} \right)_{T, P, \mu} \quad (1.3)$$





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The value of the variable 'b' is determined by the specific mechanism of electrode reactions, and experimentally measuring this Variable serves as a crucial method for analyzing and understanding the underlying reaction mechanism. The Tafel slope is obtained from the linear region of a plot of overpotential (η) versus the logarithm of the current ($\log i$). Each unique combination of chemical pathways and the rate-determining step produces a specific Tafel slope value, as indicated in Table 1.3. Nevertheless, various distinct processes often lead to the same Tafel slope (b) value. Therefore, slope by itself, like any other kinetic characteristic, cannot be utilized to ascertain a reaction's mechanism.

Determination of kinetic parameters

Transfer coefficient / symmetry factor

Electrochemical reactions possess the unique capability to regulate reaction rates across a broad range by merely altering the applied potential at the metal-electrolyte interface, without the need to change the temperature. This allows precise rate control under stable thermal conditions. The overpotential, representing the excess potential beyond the equilibrium value, is not fully efficient in driving the reaction. Only a fraction, denoted as α , contributes to accelerating the reaction in a specific direction, while the remaining portion does not directly influence the reaction's progress. This fraction, known as the transfer coefficient (α), possesses a unique value corresponding to each electrochemical reaction [20]. It serves as a crucial parameter in electrode kinetics, influencing the reaction dynamics. The transfer coefficient can be determined through various methodologies.

Tafel slope method

The classical approach remains, by far, the most dependable method for slow electron transfer reactions.. For anodic and cathodic reactions, α is obtained using equations

$$\frac{1}{b_c} = \frac{\alpha_c (nF)}{RT} \quad (1.4)$$

Here α_c is the transfer co-efficient for the cathodic reaction and

$$\frac{1}{b_a} = \frac{\alpha_a (nF)}{RT} \quad (1.5)$$

Here α_a is the transfer co-efficient for the anodic reaction

The above method can be applied for fast electrode process, provided mass transfer polarization effects are eliminated and Tafel slope free of such contribution is used. For this appropriate transients under galvanostatic, potentiationstatic or coulometric conditions must be obtained. By suitable extrapolation based on solution provided for mass transfer problems, the plot without mass transfer can be obtained and hence α . The transfer coefficient (α) can be determined experimentally using a straightforward approach. When the electrode reaction proceeds at a relatively slow rate and exhibits a low exchange current density, a steady-state potential can be established for a given applied current density, without the influence of diffusion, thus avoiding the generation of concentration overpotential. In these conditions, the flow of steady-state current density results solely in an activation overpotential, which is readily measurable. By applying a series of current densities, one can create plots of $\Delta\phi$ versus $\log i$ and η versus $\log i$. The slope of these plots, obtained under constant reaction concentrations, provides the value of α through established equation.

$$\frac{dE}{d \log i} = \frac{2.3 RT}{\alpha F} \quad (1.6)$$

Where α denotes transfer coefficient for the backward reaction.

$$\frac{dE}{d \log i} = \frac{2.3 RT}{\alpha F} \quad (1.7)$$

Where α denotes transfer co-efficient for the forward reaction.

For simple reaction, the transfer co-efficient alone may occasionally give some information regarding the mechanism of reaction.



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Tafel plots, based on the linear sweep voltammetry data to extract the Tafel slopes and exchange current density (i_0) values for various electrodes, utilizing the following equation.[21].

$$\eta = a + b \log I \quad (1.8)$$

where

$$b = \frac{RT}{\alpha nF} = \frac{60 \text{ mV/dec}}{\alpha} \quad (1.9)$$

and α is the transfer coefficient which may be obtained using

$$\alpha = \frac{\gamma}{\nu} + q\beta \quad (1.10)$$

where γ is the number of steps preceding the rate determining step, ν is the stoichiometric coefficient (1 for the given mechanism), q equals 0 for chemical steps and 1 for electron transfer steps, and β is the symmetric factor, which is 0.5 for most systems of interest [22]. Figure 1.7 The Tafel plots related to the PoPD-Pt and PoPD-Pt-Ru nanocomposites are illustrated. For PoPD-Pt, a Tafel value of 118 mV/dec was observed, closely matching the theoretical value expected for the one-electron transfer reaction's rate-limiting step. (Eq. 1.1) [23]. The changes in the electrocatalyst surface properties likely explain the increase in Tafel slopes for the PoPD-Pt-Ru nanocomposite electrodes, which gradually rise from 118 to 168 mV/dec as the Ru content increases. This trend indicates a substantial impact of Ru concentration on the catalytic performance and effectiveness of the nanocomposites. In comparison, Tafel slopes for formic acid oxidation in bulk Pt-Ru alloys have been reported to range between 180 and 195 mV/dec, highlighting different catalytic mechanisms in these systems.[25]. The intercepts of the Tafel plots are instrumental in determining the exchange current density value (i_0). The i_0 values obtained at the PoPD-Pt-Ru electrodes are larger compared to that at the PoPD-Pt electrode. Among the PoPD-Pt-Ru electrodes, the exchange current density (i_0) rises steadily until it reaches the PoPD-Pt-Ru (1:1) electrode. Beyond this point, i_0 decreases with the further addition of ruthenium (Ru) content. The catalyst configuration of PoPD-Pt-Ru (1:1) achieves a peak exchange current density (i_0) of 42 $\mu\text{A}/\text{cm}^2$, indicating optimal electrocatalytic performance. In contrast, an increase in Ru content results in a lower (i_0), a pattern widely reported in the literature. This decline in catalytic activity is attributed to the incorporation of additional Ru atoms, which leads to a dilution of the available Pt surface sites necessary for effective catalysis. As Ru replaces Pt sites, the overall efficacy of the catalyst is compromised.[25]. The optimal composition of Pt and Ru nanoparticles dispersed on PoPD, which promotes rapid kinetics in the tested electrodes, can be ascribed to an elevated exchange current density, an increased If/Ir ratio, and superior electrocatalytic performance observed in the PoPD-Pt-Ru (1:1) configuration.

Stability

Chronoamperometric analysis was employed to evaluate the long-term durability of the PoPD-Pt-Ru (1:1) electrode in formic acid oxidation, as depicted in Fig. 1.8. Performed at +400 mV over a duration of three hours, the findings reveal that the PoPD-Pt-Ru (1:1) electrode demonstrates the slowest rate of current decay and sustains the highest current density throughout the testing period. Consequently, it can be inferred that the PoPD-Pt-Ru (1:1) electrode delivers superior electrocatalytic performance for formic acid oxidation compared to its PoPD-Pt counterpart.

CONCLUSION

This review thoroughly examines the electrocatalytic performance of electrochemically synthesized PoPD-Pt and PoPD-Pt-Ru materials for formic acid oxidation. The PoPD-Pt-Ru nanocomposites, synthesized via chronoamperometry, incorporate a constant platinum content while varying the ruthenium concentrations. Their catalytic performance in formic acid oxidation is rigorously analyzed. Among the catalysts explored, the PoPD-Pt-Ru (1:1) nanocomposite outperforms the others, exhibiting the least surface poisoning, highest current output, maximum exchange current density, and improved long-term stability.





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Table.1: Characteristic FT-IR bands (cm⁻¹) of PoPD

(C-C) and (C-H) Stretching vibration of benzene nuclei Quinoid Benzeneoi d	Out-of-plane (C-H) Bending	(N-H) Stretching Phenazine	(C-N) Stretching Vibration	(C=N) Stretching SO ₄ ²⁻ Vibration
1592	1536	2930	3500- 3000	840
				1351
				1593
				1537
				1110
				619

Table.2: The oxidation of 0.5 M formic acid, analyzed through voltammetric measurements at PoPD-Pt and PoPD-Pt-Runanocomposite electrodes, provides insights into their catalytic behavior.

Electrodes	Peak Forward current (I _f) (μA)	Peak Reverse current (I _r) (μA)	I _r /I _f ratio
PoPD-Pt	144	710	0.2
PoPD-Pt-Ru 1:0.25	1503	1603	0.9
PoPD-Pt-Ru 1:0.5	1617	1787	0.9



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PoPD-Pt-Ru 1:1	1677	1504	1.1
PoPD-Pt-Ru 1:2	1501	1267	1.1
PoPD-Pt-Ru1:4	1140	1101	1.0

Table.3 Kinetic data

Electrodes	Tafel slope (mV/dec)	Exchange current density (i_0) ($\mu\text{A}/\text{cm}^2$)
PoPD-Pt	118	1.5
PoPD-Pt-Ru 1:0.25	130	2.7
PoPD-Pt-Ru 1:0.5	132	10.5
PoPD-Pt-Ru 1:1	150	42.3
PoPD-Pt-Ru 1:2	162	30.1
PoPD-Pt-Ru 1:4	168	15.7

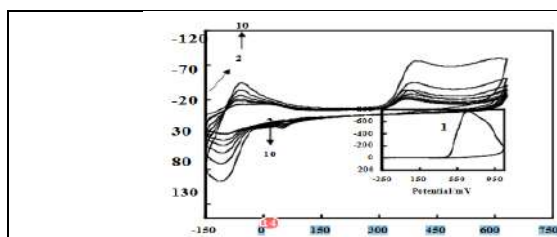


Figure. 1: PoPD growing cyclic voltammetrically at 50 mV s⁻¹ on a GCE (0.07 cm²) using a pH 1 solution containing 50 mm monomer and 0.2 M Na₂SO₄. The cycle number can be seen by the numbers in the visual representation. First cycle shown in the inset.

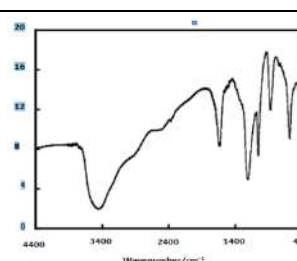


Figure.2:APoPD'sFT-IRspectrum

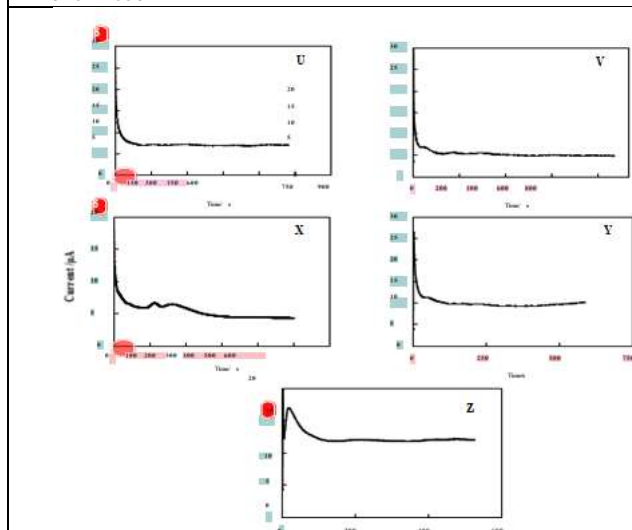


Fig.3 Current vstime curves for the electrodeposition of Pt and Runanocomposites on PoPD modified GCE. (U) PoPD-Pt-Ru (1:0) (V) PoPD-Pt-Ru (1:0.25) (X) PoPD-Pt-Ru (1:0.5) (Z) PoPD-Pt-Ru (1:1) (E) PoPD-Pt-Ru (1:2) Potential applied -250 mV vs SCE.

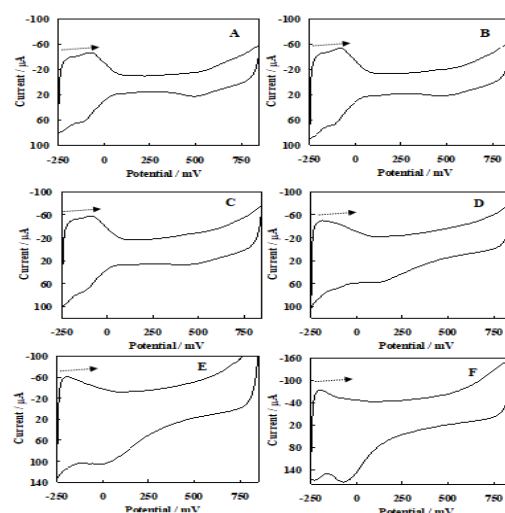


Fig. 4 The background cyclic voltammograms of modified GCEs, including (A) PoPD-Pt-Ru (1:0), (B) PoPD-Pt-Ru (1:0.25), (C) PoPD-Pt-Ru (1:0.5), (D) PoPD-Pt-Ru (1:1), (E) PoPD-Pt-Ru (1:2), and (F) PoPD-Pt-Ru (1:4), were obtained in 0.2 M Na₂SO₄ at pH 1 using a rate of scanning at 50 mV s⁻¹.





Fig. 5 Cyclic Voltammetry of (a) PoPD-Pt and (b) PoPD-Pt-Ru (1:0.25) Electrodes in 0.2 M Na_2SO_4 with 0.5 M Formic Acid at pH 1 using a Scan Rate of 5 mV s^{-1}

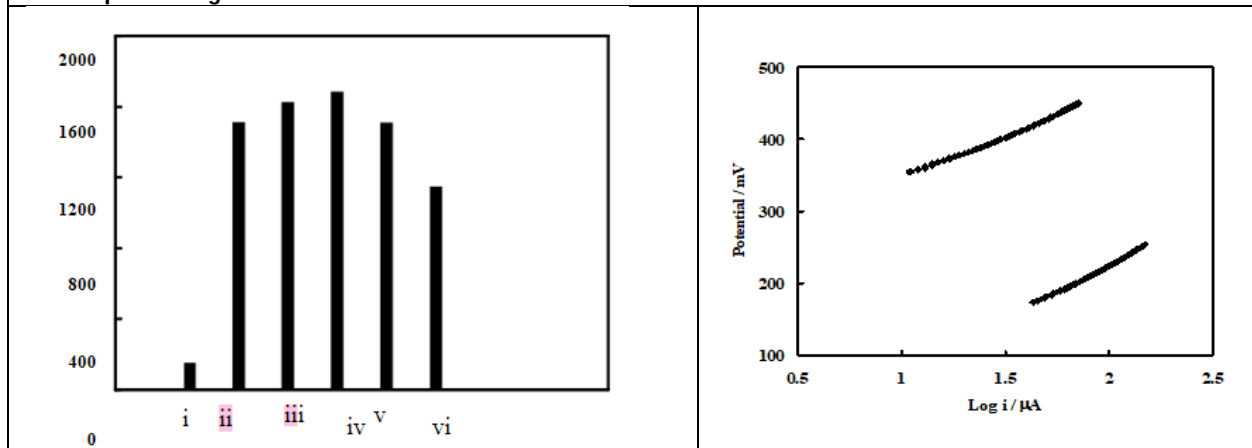


Fig. 6 Evaluation of Electrocatalytic Performance of Nanocomposites for Formic Acid Oxidation: (i) PoPD-Pt, (ii) PoPD-Pt-Ru (1:0.25), (iii) PoPD-Pt-Ru (1:0.5), (iv) PoPD-Pt-Ru (1:1), (v) PoPD-Pt-Ru (1:2), and (vi) PoPD-Pt-Ru (1:4).

Fig.7 Tafel plots for PoPD-Pt and PoPD-Pt-Runanocomposites.

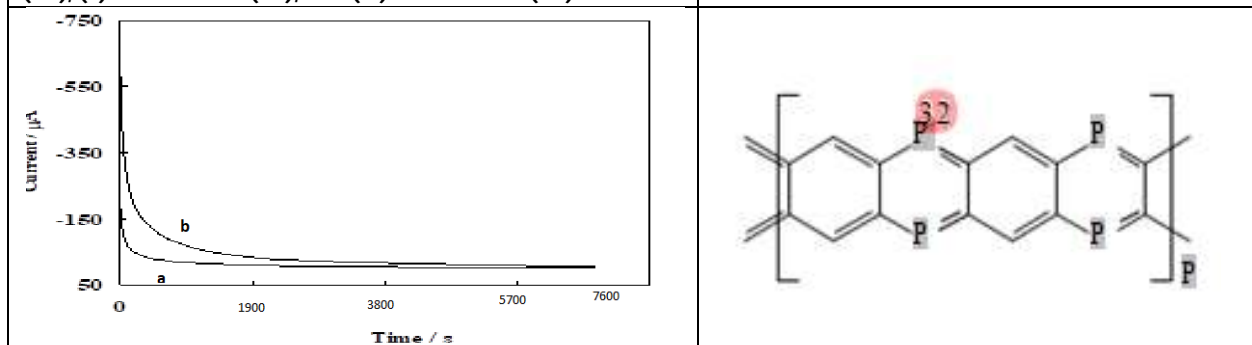
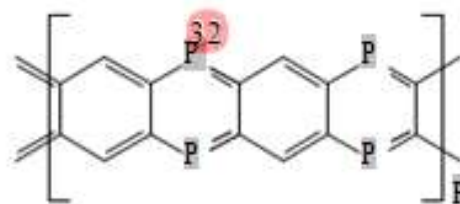


Fig. 8 The oxidation of formic acid in 0.2 M Na_2SO_4 at pH 1, with 0.5 M formic acid, was investigated through chronoamperometric profiles for (a) PoPD-Pt and (b) PoPD-Pt-Ru (1:1) catalysts at +375 mV



Scheme .1. Ladder structure of PoPD





Imeglimin Hydrochloride: A Review of Analytical Methods

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ABSTRACT

Imeglimin hydrochloride, a novel therapeutic agent, was developed along with a new class of oral antidiabetic drugs known as the Glimins which is used to treat type 2 diabetes mellitus (T2DM). Its mode of action is unique in that it improves both insulin secretion from the pancreas and insulin sensitivity in peripheral tissues through its dual effect on mitochondrial function. This dual action provides a comprehensive strategy to glycemic management by addressing insulin resistance and reduced insulin secretion, two of the key pathophysiological components of type 2 diabetes. Clinical trials have demonstrated that Imeglimin is useful in reducing blood glucose levels, and its safety profile is comparable to that of other anti-diabetic drugs. In addition to its efficacy, its distinct mode of action makes it a viable option for combination therapy with other anti-diabetic drugs to help patients with type 2 diabetes attain ideal glucose control. The fact that Imeglimin hydrochloride has been approved in Japan highlights its potential as a treatment and provides avenues for further review and approval in other global markets. As the first drug in its class, Imeglimin hydrochloride offers patients with uncontrolled diabetes the chance for improved outcomes despite available treatment options. This is a promising development in the treatment of type 2 diabetes.

Keywords: Imeglimin hydrochloride, Blood glucose, type 2 diabetes mellitus, glimins, insulin, pancreatic beta cell.





INTRODUCTION

The most common symptom of type 2 diabetes mellitus is elevated blood glucose levels. Numerous micro vascular and macro vascular problems arise from poorly managed or untreated blood glucose levels. Numerous drugs are available to manage type 2 diabetes mellitus and stop the disease's progression in order to avoid these consequences. But the majority of drugs currently on the market only address a small number of the physiological abnormalities brought on by diabetes, and they may have unpleasant side effects that make taking the drug as prescribed unlikely [1]. A novel category of oral medications for diabetes, referred to as "glimins," encompasses Imeglimin, tetrahydro triazine, (Figure 1) and various other compounds. Its mechanism of action, which targets numerous pathways to give glycaemic control, is currently understood. The possibility of discovering it was facilitated through further chemical alteration of a primary compound and testing its effects in living organisms, specifically focusing on its ability to reduce high blood sugar levels in rodents. Imeglimin has proven to be effective in lowering blood sugar levels in both Japanese and Caucasian patients with type 2 diabetes (T2D) in real-world clinical settings. It has also shown generally positive safety and tolerability profiles and a low incidence of severe hypoglycaemia in a number of clinical trials involving combinations with metformin, dipeptidyl peptidase-4 inhibitors, insulin, and other drug classes. [2-5]. In June 2021, Japan approved the first use of Imeglimin for T2D patients. The pivotal phase III TIMES program's positive results, along with a wealth of preclinical and clinical information, provided the basis for the Japanese approval [6]. Imeglimin may be a safe and helpful supplement to other drugs that are often used to treat type 2 diabetes in addition to its usual side effects because it appears to function differently from other oral anti-diabetic medicines. Clinical studies have shown that Imeglimin is effective in reducing blood glucose levels when used alone or in conjunction with other antidiabetic medications. Moreover, its unique mechanism of action suggests a low risk of hypoglycaemia, a common concern with some diabetes medications. Additionally, studies have shown potential benefits beyond glycaemic control, such as improvements in markers of cardiovascular health and renal function. In clinical trials, Imeglimin has also shown a favourable safety profile, with most reported adverse effects being moderate and temporary. Its tolerability, coupled with its mechanism of action, positions Imeglimin as a promising option for patients with T2DM who may have contraindications or intolerance to existing therapies [7, 8].

Increased hepatic glucose synthesis and decreased peripheral glucose absorption by insulin-sensitive tissues, along with higher β -cell mortality and insufficient insulin production, are the two primary pathophysiological defects in type 2 diabetes. A gradual decrease of β -cell mass and function contributes to the deterioration of glycaemic management in type 2 diabetes, which is a progressive disease [9-11]. According to cross-sectional research, around 56% of individuals with type 2 diabetes have a HbA1c $\leq 7.0\%$. But when diabetes worsens over time, glycaemic control deteriorated even further, necessitating the inclusion of more intricate insulin regimens to keep 50% of patients at HbA1c $\leq 7.0\%$. Metformin is the sole pharmacological intervention recommended for people with type 2 diabetes, along with healthy daily habits, according to the American Diabetes Association and the European Association for the Study of Diabetes. An annual failure rate of 17% has been linked to metformin therapy; however, in patients who began taking the drug within three months of receiving a type 2 diabetes diagnosis, this rate dropped to 12%. Apart from the decline in glycaemic control, the current treatments include drawbacks such as weight gain, hypoglycaemia, cardiovascular problems, and contraindications that prevent their usage [12, 13].

Physicochemical Properties

Physicochemical properties show the drug profile of imeglimin hydrochloride. It includes molecular formula, molecular weight, IUPAC name of drug, density, vapour pressure, solubility, boiling point etc. These are used to identify the drug stability, efficacy, safety and toxicity. (Table 1)

Pharmacokinetic Properties

Pharmacokinetic properties describe how the body interacts with a drug, including absorption, distribution, metabolism, and excretion. These properties influence the drug's effectiveness and potential side effects, guiding dosing and administration. (Table 2)



**Vijayalakshmi et al.,****Mechanism of Action**

Imeglimin is a unique therapeutic intervention with promising potential as a novel antidiabetic agent due to its multifaceted mechanism of action. It appears that Imeglimin either mitigates or reverses the three main pathways linked to type 2 diabetes. Among them are:

Suppression of Hepatic Glucose Production

- Imeglimin inhibits glucose synthesis in isolated rat liver cells and liver slices.
- Concentration-dependent decrease in glucose production observed in isolated cells, ranging from 9% to 80%.
- Inhibition of glucose production in liver slices was also observed, with reductions ranging from 14% to 84%.
- Imeglimin molecular effects achieved by inhibiting PEPCK and G6Pase in separated rat hepatocytes and blocking lactic acidosis via mitochondrial-dependent route [19, 20].

Stimulation of Skeletal Muscle Glucose Uptake

- Effective in muscle cell cultures, increasing glucose uptake.
- Observed at 0.5 mol/L dose, 3.3-fold increase at maximal dose (2 mmol/L).
- Significant increase in glucose absorption in streptozotocin-diabetic rats' soleus and gastrocnemius muscles.
- Uptake returned to normal at 50 mg/kg and 100 mg/kg for diabetic rats.
- Potential pathways include increased phosphorylation of protein kinase B (Akt), expression of glucose transporter-4, and control of insulin receptor substrate phosphorylation [21, 22].

Impairment of Pancreatic β -cells

- Translational medicine study shows Imeglimin improves hyperglycemia reaction in T2D patients.
- Imeglimin increases HOMA- β score, a gauge of β -cell function, compared to placebo.
- Imeglimin reduces proinsulin/insulin ratio, indicating improved β -cell activity.
- Imeglimin prevents pancreatic β -cell apoptosis and glucose-induced β -cell death, preserving functional β -cell mass.
- In absence of cytokines, Imeglimin lowers basal apoptosis in rat pancreatic β -cells by 10%.
- In presence of cytokines, Imeglimin reduces apoptotic cell death by 37% and 25%.
- Imeglimin has strong protective effect against glucose-induced toxicity [23].

Additional Effects

- Imeglimin regulates mitochondrial function, reduces reactive oxygen species, and protects cells from apoptosis.
- Study shows improved cardiac performance and increased tissue perfusion in left ventricle.
- Improvements associated with reduced albuminuria, increased coronary artery endothelium-dependent relaxation, decreased ROS generation, and decreased renal interstitial fibrosis.
- Rates of tubular damage and interstitial inflammation remained unchanged [1, 24].

Medicinal Uses

It is mainly used in the treatment of type 2 diabetes mellitus. Imeglimin is intended to address certain glucose metabolism flaws. It's a member of the class of drugs known as dpp-4 inhibitors, sometimes known as gliptins. It helps your body produce more insulin after a meal and helps stop your body from releasing too much glucose, or sugar, into the bloodstream. It lowers your body's blood glucose levels in this way. By doing this, major diabetes problems like renal failure and blindness are less likely to occur. Increasing insulin sensitivity, lowering gluconeogenesis, boosting β -cell activity, boosting mitochondrial function, and lowering oxidative stress are some advantages of these pathways to enhance glucose homeostasis [25]. It functions in two ways: 1) it increases the amount of glucose-stimulated insulin secretion (gsis) and preserves cell mass; 2) it improves insulin action, which may include a decrease in the amount of glucose produced by the liver and an increase in insulin signalling in the muscle cells of the skeleton and liver [26].

Following are a few typical drug applications for the treatment of type 2 diabetes:

1. Oral antidiabetic medications
2. Insulin therapy





3. Combination therapy
4. Blood pressure and cholesterol
5. Lifestyle modifications [27]

ADVERSE DRUG REACTIONS

Imeglimin hydrochloride, also known as Imeglimin HCL, has the potential to cause negative effects like any medicine, albeit not everyone will. Imeglimin HCL adverse effects that could occur include:

1. Symptoms related to the digestive system: they may include bloating, diarrhoea, vomiting, and nausea. These are some of adverse effects that are most frequently observed [28].

2. Hypoglycaemia (low blood sugar): similar to related Antidiabetic drugs, Imeglimin HCL may occasionally result in hypoglycaemia, particularly when taken with insulin or other glucose-lowering treatments.

3. Allergic responses: Imeglimin HCL may occasionally cause allergic responses in people. These reactions can include rash, itching, swells, or trouble breathing. As soon as there are any indications of an allergic response, you should get medical help.

4. Headache: Imeglimin HCL may cause migraines in certain individuals [29].

5. Dizziness: some people who use Imeglimin HCL may experience light-headedness or drowsiness.

6. Elevated liver enzymes: Imeglimin HCL occasionally causes a rise in liver enzymes, which may be a sign of injury or damage to the liver. Throughout medication, liver function may need to be monitored [30].

7. Other side effects: joint discomfort, upper respiratory tract infections, and infections in the urinary tract are less frequent side effects that may occur.

Contraindications

Imeglimin hydrochloride, also known as Imeglimin HCL, has certain contraindications and may not be appropriate for all patients. A medicine should not be administered under certain circumstances or conditions, known as contraindications. Imeglimin HCL contraindications include the following:

1. Hypersensitivity: this drug should not be used by anyone who has been found to be allergic to Imeglimin HCL or either of its constituents [31].

2. Severe renal impairment: the kidneys are the main organs in the body that remove Imeglimin HCL. Imeglimin HCL should thus not be used by those with significant renal impairment (egfr < 30 ml/min/1.73 m²) because of the possibility of drug build-up and an elevated risk of side effects.

3. End-stage renal disease: since both the safety and effectiveness of Imeglimin HCL have not been demonstrated in this group of patients, it is not recommended for those with end-stage renal disease, also known as esrd, who need dialysis.

4. Breastfeeding and pregnancy: it is unknown if Imeglimin HCL is safe to use during these times. Therefore, until the possible benefits exceed the risks when done under the supervision of a healthcare provider, it ought to be avoided by pregnant or nursing women [32].

5. Paediatric demographic: because there is insufficient information about the safety and effectiveness of Imeglimin HCL in this demographic, it is not advised for use in kids and adolescents below the age of 18. [33].

6. Severe hepatic impairment: although the liver is the primary organ involved in the metabolism of Imeglimin HCL, taking it in people with hepatic impairment is usually not contraindicated. However, those who have profound liver damage may need to alter their dosage and exercise caution. People who are thinking about using Imeglimin HCL or who have been offered it should talk to their healthcare professional about their medical conditions, including any pre-existing diseases or medications they are currently taking. This makes it easier to make sure the drug is suitable and secure for their particular circumstance [34-36].

Drug Interactions

Drug-Drug Interactions: Imeglimin interacts with an anti-depressant (bupropion), drugs used to treat glaucoma, antibiotics (cephalexin, ciprofloxacin), anti-acidity drugs (cimetidine), heart condition drugs (digoxin), anti-epileptic drugs (topiramate, lamotrigine), and heart-related chest medicine (ranolazine) [37].



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1. Hypoglycaemia Risk: Combining multiple antidiabetic medications, such as insulin, sulfonylureas (e.g., glipizide, glyburide), or meglitinides (e.g., repaglinide), can increase the risk of hypoglycaemia (low blood sugar).
2. Liver Enzyme Interactions: Certain Antidiabetic medications, like thiazolidinediones (e.g., pioglitazone), can affect liver enzyme levels and may interact with drugs metabolized by the liver [38].
3. Drug Interactions with Oral Antidiabetic Agents: Some medications can alter the effectiveness of oral antidiabetic agents, including metformin, DPP-4 inhibitors (e.g., sitagliptin), SGLT2 inhibitors (e.g., empagliflozin), or GLP-1 receptor agonists (e.g., liraglutide) [39].
4. Beta-blockers: Non-selective beta-blockers (e.g., propranolol) can mask the symptoms of hypoglycaemia, making it harder for individuals to recognize low blood sugar levels [40].
5. Corticosteroids: Corticosteroids can increase blood sugar levels and counteract the effects of antidiabetic medications [41].
6. Diuretics: Thiazide diuretics, such as hydrochlorothiazide, can increase blood sugar levels and may require adjustments to antidiabetic medication dosages [42].
7. Certain Antibiotics: Some antibiotics, particularly fluoroquinolones and macrolides, may affect blood sugar levels and require monitoring in individuals taking antidiabetic medications [43-44].

Marketed Formulation

The different solid-tablet dosage forms that are available from various pharmaceutical companies are listed here. The dosage, price, brand name, and company name are all included in each entry. These tablets are available in a variety of doses ranging from 500mg to 1000mg and are made by firms such as Zydus Life Science Limited, Lupin Ltd, Zydus Healthcare Ltd, La Renon Healthcare Pvt Ltd, Zuventus Healthcare Ltd, and Sumitomo Dainippon Pharma Co. Ltd. Prices differ between brands and dosages, giving customers options according to their requirements and financial constraints. (Table 3)

Clinical Studies

Clinical trials are investigations conducted on humans to evaluate a medicinal, surgical, or behavioral intervention. Researchers mostly use these studies to assess the safety and efficacy of novel treatments in humans. Clinical trials have been conducted for Imeglimin Hydrochloride, and the following table summarizes the information that has been obtained from the trials. (Table 4)

Analytical Methods For Imeglimin HCL

An analytical method is a procedure that employs a range of techniques to ascertain a sample's composition either quantitatively or qualitatively. Developed analytical methods can be used to identify, segregate, quantify, and obtain further information on the chemical components in medicinal compounds intended for commercial manufacture. The following are some of the analytical methods developed for Imeglimin Hydrochloride. (Table 5)

CONCLUSION

An investigational drug for type 2 diabetes shows promise in improving glycaemic control by targeting multiple pathways in glucose metabolism. Clinical trials have demonstrated its potential efficacy and safety profile. However, further research is needed to confirm its long-term benefits and establish its place in diabetes management protocols. Imeglimin HCL is an innovative oral anti-diabetic medication that helps patients with type 2 diabetes better manage their glucose metabolism by focusing on mitochondrial bioenergetics. Clinical trials have demonstrated encouraging outcomes as it efficiently lowers blood sugar levels and improves insulin sensitivity. In summary, Imeglimin HCL presents a novel strategy for diabetes management and exhibits promise as a useful supplement to the current range of care available to those with type 2 diabetes.





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Table.1: Physicochemical Properties of Imeglimin HCL

Properties	Observations
Appearance	White to off-white colour powder [14]
Molecular formula	C ₆ H ₁₄ ClN ₅
Molecular weight	191.66 g/mol [15]
Molar Volume	119.6±7.0 cm ³ [14]
IUPAC Name	(4R)-6-N,6-N,4-trimethyl-1,4-dihydro-1,3,5-triazine-2,6-diamine:hydrochloride
Solubility	≥29.9 mg/ml in Dimethyl sulfoxide; ≥50.3 mg/ml in ethanol; ≥62.7 mg/ml in water
UV	239 nm (maximum)
PKa	10.21 [15]
Density	1.3±0.1 g/cm ³
Boiling Point	239.9±23.0 °C at 760 mmHg
Vapour Pressure	0.0±0.5 mmHg at 25°C
Polarizability	16.7±0.5 10 ⁻²⁴ cm ³
Surface Tension	44.7±7.0 dyne/cm [14]

Table.2: Pharmacokinetic Properties of Imeglimin HCL

Parameters	Description
Recommended dose	1000 -1500 mg twice daily [17]
C _{max}	After dosage, C _{max} was obtained within 1.5 and 4 hours.
T _{max}	3.5 hours.
t _{1/2}	13 hours.
Half life	10–20 h in healthy volunteers.
Protein binding	1.2%–6.4%
Bioavailability	Bioavailability of Imeglimin depends on dose like increasing drug doses with decreases in bioavailability and ranges between 20 to 50%.
Absorption	50 and 80 % of the Imeglimin absorbed in the gastrointestinal tract by passive and active transport. It is possible to extend absorption for up to four hours [16].
Distribution	It is distributed rapidly and extensively to the organ [18].
Metabolism	Both humans and animals have poor metabolisms [16]. It has a lack of ability to inhibit CYP450 [18].
Excretion	In urine and faeces, around 98% of the absorbed radioactive dose was eliminated as an unchanged compound [16].



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Table.3: List of Marked Formulation of Imeglimin HCL

S. No	Type of dosage form	Brand name	Company name	Dose	Prize
1	Solid-Tablet	Imeglyn®500	Zydus life science limited	500mg	Rs.69
2	Solid-Tablet	Lupimeg 1000	Lupin Ltd	1000mg	Rs.150
3	Solid-Tablet	Imeglyn®1000	Zydus life science limited	1000mg	Rs.98
4	Solid-Tablet	Imeglyn SR 1000	Zydus Healthcare Ltd	1000mg	Rs.119
5	Solid-Tablet	Imezemic™1000	La Renon Healthcare Pvt Ltd	1000mg	Rs.227.80
6	Solid-Tablet	Lupimeg 500	Lupin Ltd	500mg	Rs.100
7	Solid-Tablet	Zuglimin™500	Zuventus Healthcare Ltd	500mg	Rs.80
8	Solid-Tablet	Twymeg®500	Sumitomo Dainippon Pharma co.,Ltd.,	500mg	\$99

Table.4: Clinical Studies for Imeglimin HCL

S. No	Summary	Reference
1	Type of study: comparative studies Drugs used: Imeglimin, metformin and placebo Parameters observed: AUC (PG) and AUC (0-6h), FPG, and HbA1c. Result: Imeglimin showed effective in reducing AUC (PG), AUC (0-6h), FPG, and HbA1c as metformin.	45
2	Type of study: Combination type studies Drugs used: Imeglimin with metformin, Imeglimin with placebo Parameters observed: HbA1c and FPG Result: Imeglimin with metformin decreased HbA1c levels by 0.65% , compared Imeglimin with placebo decreased levels by 0.21%.	46
3	Type of study: Controlled study Drugs used: Imeglimin with Placebo Parameters observed: HbA1c , FPG Result: assessing the efficacy, safety and tolerability of Imeglimin.	47
4	Type of study: Controlled study Drugs used: Imeglimin with placebo Parameters observed: alanine aminotransferase (ALT) and gamma-glutamyl transferase (GGT), liver function test. Result: Significant decrease in ALT and GGT, thus showing improved liver function.	48
5	Type of study: Controlled study Drugs used : Imeglimin with placebo Parameters observed: HbA1c and FPG Result: Imeglimin shows sensitivity	49
6	Type of study: Comparative study Drugs used : Imeglimin with Placebo Parameters observed: HbA1c and GIT effects of different doses. Result: 500mg and 1000mg (BD) shows the expected results i.e. decreased in HbA1c and no GIT side effects. But 1500mg (BD) show slight increase in GIT side effects and dramatic reduction in HbA1c levels	50
7	Type of study: Controlled Study Drugs used : Imeglimin with placebo Parameters observed: HbA1c and FPG	51





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	Result: Imeglimin shows reduce hba1c levels when compared with placebo	
8	<p>Type of study: Parallel group study</p> <p>Drugs used :Imeglimin , dipeptidyl peptidase-4 inhibitors, thiazolidinediones, alpha-glucosidase inhibitors, glinides , metformin , sodium-glucose transport protein 2 inhibitors , sulphonylureas , glucagon-like peptide 1 receptor agonists.</p> <p>Parameters observed: Mean HbA1c</p> <p>Result: Co-administration of Imeglimin and the other studied hypoglycaemic agents shows the following HbA1c: dipeptidyl peptidase-4 inhibitors (-0.92%), thiazolidinediones (-0.88%), alpha-glucosidase inhibitors (-0.85%), glinides (-0.70%), metformin (-0.67%), sodium-glucose transport protein 2 inhibitors (-0.57%), sulphonylureas (-0.56%), glucagon-like peptide 1 receptor agonists (-0.12%).</p>	52
9	<p>Type of study: Combination study</p> <p>Drugs used :Imeglimin and insulin, Placebo</p> <p>Parameters observed: HbA1c</p> <p>Result: Imeglimin with insulin shows 0.64% HbA1c and Placebo with insulin and followed by Imeglimin with insulin shows 0.54% HbA1c.</p>	53
10	<p>Type of study: Randomized study</p> <p>Drugs used :Imeglimin HCL, Metformin and placebo</p> <p>Parameters observed:Glucose area under the curve [AUC]) and 3 H-glucose tolerance test [OGTT]</p> <p>Result: The results revealed increase in insulin secretion was accompanied by an increase in beta cell glucose sensitivity</p>	54
11	<p>Type of study: Comparative study</p> <p>Drugs used :Imeglimin HCL, placebo</p> <p>Parameters observed: HbA1c</p> <p>Result: The results show the improved HbA1c in Japanese patients with type 2 diabetes compared to placebo and had a similar safety profile to placebo.</p>	55
12	<p>Type of study: Comparative study</p> <p>Drugs used :Imeglimin HCL (1000mg, monotherapy and oral combination therapy with α-glucosidase inhibitor, biguanide , dipeptidyl peptidase-4 inhibitor (DPP4-I), glinide , glucagon-like peptide-1 receptor agonist (GLP1-RA), sodium-glucose co-transporter-2 inhibitor , sulphonylurea or thiazolidinedione.</p> <p>Parameters observed: HbA1c</p> <p>Result:Imeglimin monotherapy reduced HbA1c by 0.46%; Imeglimin oral combination therapy reduced HbA1c by 0.56%-0.92%; and injectable GLP1-RA combination therapy reduced HbA1c by 0.12%. Patients who received a DPP4-I in addition to Imeglimin experienced the largest net HbA1c reduction (0.92%).</p>	56
13	<p>Type of study: Comparative randomized study</p> <p>Drugs used :Imeglimin HCL and placebo</p> <p>Parameters observed:glycated haemoglobin (HbA1c)</p> <p>Result: Imeglimin HCL shows significant decrease in mean hba1c of -0.60% compared to placebo.</p>	57
14	<p>Type of study: Meta- Analysis study</p> <p>Drugs used :Imeglimin HCL (1000mg BID)</p> <p>Parameters observed: HbA1c</p> <p>Result: The findings demonstrated that, in comparison to the placebo, Imeglimin 1000 mg BID considerably lowered HbA1c without causing any heterogeneity.</p>	58





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Table.5: Analytical Methods for Imeglimin HCL

S. No	Summary	Reference
1	<p>Analytical Method: High performance liquid chromatography Phase : Reverse Phase Column : Hypersil ODS (150 mm X 4.6 mm), 5µm Mobile Phase: Buffer pH 3.0 and Methanol (75:25 v/v) Runtime: 5.0 min Wavelength: 234 nm</p> <p>The parameters observed are System suitability test, linearity range, accuracy, precision, intermediate precision (Ruggedness), method precision, robustness, specificity</p>	59
2	<p>Analytical Method: Ultra High-performance liquid chromatography Phase : Reverse Phase Column : Hypersil gold ODS end capped RP column (150 mm X 4.6 mm), 3µm Mobile Phase : Water and Acetonitrile (15:85 %v/v) Runtime: 10 min Wavelength: 240 nm</p> <p>The parameters observed are Specificity, linearity, precision, accuracy robustness, LOD and LOQ were determined for method validation.</p>	60
3	<p>Analytical Method: UV Visible Spectroscopy Solvent: Distilled Water Wavelength: 237 nm Absorbance: 0.488 Concentration : 10 µg/mL</p> <p>The parameters included are limit of detection, limit of quantification, linearity, accuracy, precision, and assay of marketed formulation Imeglimin hydrochloride.</p>	61
4	<p>Analytical Method: UV Visible Spectroscopy Solvent: Distilled Water Wavelength : 239 nm Absorbance range : 0.2225 to 1.3630 Concentration range : 2.5 - 15 µg/mL</p> <p>The Parameters observed are linearity, accuracy, precision, and ruggedness. The recovery studies and precision were found to be within limits.</p>	62
5	<p>Analytical method: Chiral Liquid Chromatography Tandem Mass Spectrometry. Mobile phase: Methanol and Acetonitrile Phase: Reverse Phase Column: Chiralpak IG-3 (100×4.6mm, 3 µm) Run time: 5 mins</p> <p>The parameters observed are the drug's (+) and (–) enantiomers had retention times of 2.876 and 4.325 minutes, respectively. The objective is to distinguish the enantiomers and create a quick, accurate, and economical technique for calculating the (+) and (–) enantiomers in its composition.</p>	63





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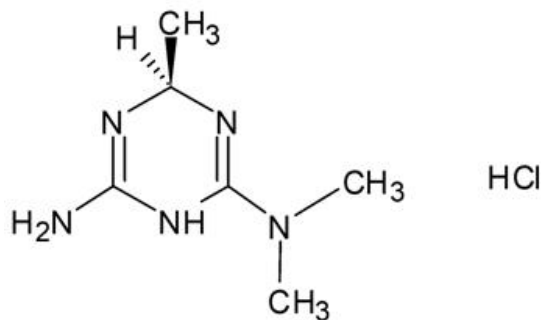


Figure.1: Chemical Structure of Imeglimin Hydrochloride





On Neutrosophic Λ_P - Open Sets in Neutrosophic Topological Spaces

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ABSTRACT

The purpose of this paper is to define a new class of neutrosophic sets namely neutrosophic Λ_P -open sets and neutrosophic Λ_P -closed sets in neutrosophic topological space. We also discuss the properties of neutrosophic Λ_P -open sets and its relation with other existing neutrosophic sets. Also, we define some neutrosophic operators such as neutrosophic Λ_P -interior, neutrosophic Λ_P -closure, neutrosophic Λ_P -Frontier, neutrosophic Λ_P -Border and neutrosophic Λ_P -Exterior and study some of its properties.

Keywords: neutrosophic Λ_P -open, neutrosophic Λ_P -closed, neutrosophic Λ_P -interior, neutrosophic Λ_P -closure, neutrosophic Λ_P -Frontier, neutrosophic Λ_P -Border and neutrosophic Λ_P -Exterior.

INTRODUCTION

Mathematics is based on exact concepts and there is no vagueness for mathematical theories. Many theories can be considered as tools for dealing with uncertainties. However, all of these theories have their own difficulties. The notion of fuzzy sets has invaded almost all branches of mathematics since its introduction by Zadeh[18]. Fuzzy sets have applications in many fields such as information theory and control theory. He introduced this concept that each element has a degree of membership function. Later, in 1986, Atanassov[2] extended the intuitionistic fuzzy set as a generalization of fuzzy set with the degree of non-membership. Further there is a restriction that the sum of these two grades is less than or equal to unity. The neutrosophic sets which is characterized by truth membership function, indeterminacy membership function and falsity membership function was initiated by Smarandache[13] in 1998.





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Later A. Salama and Alblowi[12] studied the concept of neutrosophic topological space in 2012. The class of neutrosophic semi-open and neutrosophic semi-closed were discussed by P. Iswarya and K. Bageerathi[6] in 2016. The neutrosophic sets was extended to a new class of set namely generalized closed sets in neutrosophic topological space were introduced by R. Dhavaseelan and Saied Jafari[4]. Further many other properties have been defined on neutrosophic sets using the closure and interior operator and their topological properties have been studied. In intuitionistic fuzzy topology, the concept of frontier and border were studied by Athar Kharal[3] in 2014. Later P. Iswarya[7] and K. Bageerathi extended the concept of frontier in neutrosophic topological space. A. Vadivel[16] and C. John Sundar extended the border operator using neutrosophic sets. The purpose of this paper is to introduce a new class of open sets namely neutrosophic Λ_p -open sets and neutrosophic Λ_p -closed sets. We discuss the characterization and relation with other existing neutrosophic sets. Also, we study some operators using neutrosophic Λ_p -open sets such as neutrosophic Λ_p -interior, neutrosophic Λ_p -closure, neutrosophic Λ_p -Frontier, neutrosophic Λ_p -Border and neutrosophic Λ_p -Exterior.

2. Preliminaries

Definition 2.1:[12] Let U be a non-empty fixed set. A Neutrosophic set K is an object having the form $K = \{\langle u, \mu_K(u), \sigma_K(u), \gamma_K(u) \rangle : u \in U\}$ where $\mu_K(u)$, $\sigma_K(u)$ and $\gamma_K(u)$ represents the degree of membership, the degree of indeterminacy and the degree of non-membership respectively of each element $u \in U$ to the set U . A neutrosophic set $K = \{\langle u, \mu_K(u), \sigma_K(u), \gamma_K(u) \rangle : u \in U\}$ can be identified to an ordered triple $(\mu_K(u), \sigma_K(u), \gamma_K(u))$ in $[0,1]$ on U .

Definition 2.2:[12] Let U be a non-empty set and $K = \{\langle u, \mu_K(u), \sigma_K(u), \gamma_K(u) \rangle : u \in U\}$ and $M = \{\langle u, \mu_M(u), \sigma_M(u), \gamma_M(u) \rangle : u \in U\}$ are neutrosophic sets, then

- i. $K \subseteq M \Leftrightarrow \mu_K(u) \leq \mu_M(u), \sigma_K(u) \leq \sigma_M(u)$ and $\gamma_K(u) \geq \gamma_M(u) \forall u \in U$
- ii. $K \cup M = \{\langle u, \max(\mu_K(u), \mu_M(u)), \max(\sigma_K(u), \sigma_M(u)), \min(\gamma_K(u), \gamma_M(u)) \rangle : u \in U\}$
- iii. $K \cap M = \{\langle u, \min(\mu_K(u), \mu_M(u)), \min(\sigma_K(u), \sigma_M(u)), \max(\gamma_K(u), \gamma_M(u)) \rangle : u \in U\}$
- iv. $K^c = \{\langle u, (\gamma_K(u), 1 - \sigma_K(u), \mu_K(u)) \rangle : u \in U\}$
- v. $0_{N_{tr}} = \{\langle u, 0, 0, 1 \rangle : u \in U\}$ and $1_{N_{tr}} = \{\langle u, 1, 1, 0 \rangle : u \in U\}$

Definition 2.3:[12] A Neutrosophic topology on a non-empty set U is a family $\tau_{N_{tr}}$ of neutrosophic sets in U satisfying the following axioms:

- i. $0_{N_{tr}}, 1_{N_{tr}} \in \tau_{N_{tr}}$.
- ii. $K_1 \cap K_2 \in \tau_{N_{tr}}$ for any $K_1, K_2 \in \tau_{N_{tr}}$.
- iii. $\cup K_i \in \tau_{N_{tr}}$ for every $\{K_i : i \in I\} \subseteq \tau_{N_{tr}}$.

In this case the ordered pair $(U, \tau_{N_{tr}})$ is called a neutrosophic topological space $(N_{tr}TS)$. The members of $\tau_{N_{tr}}$ are neutrosophic open set $(N_{tr}O)$ and its complements are neutrosophic closed $(N_{tr}C)$.

Definition 2.4:[12] Let $(U, \tau_{N_{tr}})$ be a neutrosophic topological space and $K = \{\langle u, \mu_K(u), \sigma_K(u), \gamma_K(u) \rangle : u \in U\}$ be a neutrosophic set in U . Then the neutrosophic closure and neutrosophic interior of K are defined as

$$N_{tr}cl(K) = \cap \{X : X \text{ is } N_{tr}\text{-closed set in } U \text{ and } K \subseteq X\}$$

$$N_{tr}int(K) = \cup \{Y : Y \text{ is } N_{tr}\text{-open set in } U \text{ and } K \subseteq Y\}$$

Definition 2.5: A neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophic locally indiscrete if every neutrosophic open set is neutrosophic closed.

Definition 2.6: A Neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is

- i. **neutrosophic semi-open**[6] if there exists a neutrosophic open set E in U such that $E \subseteq K \subseteq N_{tr}cl(K)$.
- ii. **neutrosophic pre-open**[17] if $K \subseteq N_{tr}int(N_{tr}cl(K))$ and neutrosophic pre-closed $(N_{tr}PC)$ if $N_{tr}cl(N_{tr}int(K)) \subseteq K$.
- iii. **neutrosophic regular-open**[1] if $K = N_{tr}int(N_{tr}cl(K))$ and neutrosophic regular closed $(N_{tr}rC)$ if $K = N_{tr}cl(N_{tr}int(K))$.





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- iv. **neutrosophic α -open**[1] if $K \subseteq N_{tr}int(N_{tr}cl(N_{tr}int(K)))$ and neutrosophic α -closed($N_{tr}\alpha C$) if $N_{tr}cl(N_{tr}int(N_{tr}cl(K))) \subseteq K$.
- v. **neutrosophic β -open**[11] if $K \subseteq N_{tr}int(N_{tr}cl(N_{tr}int(K)))$ and neutrosophic β -closed($N_{tr}\beta C$) if $N_{tr}cl(int(N_{tr}cl(K))) \subseteq K$.
- vi. **neutrosophic δ -open**[15] if $K = N_{tr}\delta int(K)$ and neutrosophic δ -closed ($N_{tr}\delta C$) if $K = N_{tr}\delta cl(K)$.
- vii. **Neutrosophicb-open**[5] if $K \subseteq N_{tr}cl(N_{tr}int(K)) \cup N_{tr}int(N_{tr}cl(K))$ and neutrosophic b-closed if $N_{tr}cl(N_{tr}int(K)) \cap N_{tr}int(N_{tr}cl(K))$.

The class of all neutrosophic semi-open (respectively neutrosophic pre-open, neutrosophic regular-open, neutrosophic α -open, neutrosophic β -open, neutrosophic δ -open and neutrosophic b-open) sets are denoted by $NSO_{tr}(U, \tau_{N_{tr}})$ (respectively $N_{tr}PO(U, \tau_{N_{tr}})$, $N_{tr}RO(U, \tau_{N_{tr}})$, $N_{tr}\alpha O(U, \tau_{N_{tr}})$, $N_{tr}\beta O(U, \tau_{N_{tr}})$, $N_{tr}\delta O(U, \tau_{N_{tr}})$ and $N_{tr}bO(U, \tau_{N_{tr}})$).

Definition 2.7:[10] A neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophicY-open if for every non-empty N_{tr} closed set $F \neq 1_{N_{tr}}$, $K \subseteq N_{tr}cl(N_{tr}int(KUF))$. The class of neutrosophicY-open sets is denoted by $N_{tr}YO(U, \tau_{N_{tr}})$.

Definition 2.8:[8] A neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophic generalized b-closed ($N_{tr}gbC$) if $N_{tr}bcl(K) \subseteq H$ whenever $K \subseteq H$ and H is neutrosophic open in U .

Definition 2.9:[7] Let K be a neutrosophic subset of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then the neutrosophic point $u_{a,b,c}$ is called neutrosophic frontier point of K if $u_{a,b,c} \in N_{tr}cl(K) \cap N_{tr}cl(K^c)$. The intersection of all the neutrosophic frontier points of K is called neutrosophic frontier of K and is denoted by $N_{tr}Fr(K)$. That is $N_{tr}Fr(K) = N_{tr}cl(K) \cap N_{tr}cl(K^c)$.

Definition 2.10:[16] Let K be a neutrosophic subset of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then the Neutrosophic-Border of K is denoted as $N_{tr}Br(K)$ and is defined as $N_{tr}Br(K) = K - N_{tr}int(K)$. (Equivalently, $N_{tr}Br(K) = K \cap N_{tr}int(K)$).

Definition 2.11: Let K be a neutrosophic subset of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then the Neutrosophic-Exterior of K is denoted as $N_{tr}Ext(K)$ and is defined as $N_{tr}Ext(K) = N_{tr}int(K^c)$.

Remark 2.12

- i. Every N_{tr} open set is N_{tr} -pre-open[14].
- ii. Every N_{tr} regular-open set is N_{tr} -open[1].
- iii. Every $N_{tr}\delta$ -open set is N_{tr} -open[13].

Theorem 2.13:[5] Let K be a neutrosophic set in a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then $N_{tr}pint(K) \subseteq K \cap N_{tr}int(N_{tr}cl(K))$.

3. Neutrosophic Λ_P -Open Sets

Definition 3.1: A neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophic Λ_P -open if there exist a N_{tr} -pre-open set $E \neq 0_{N_{tr}}, 1_{N_{tr}}$ such that $K \subseteq N_{tr}cl(K \cap E)$. The class of neutrosophic Λ_P -open sets is denoted by $N_{tr}\Lambda_P O(U, \tau_{N_{tr}})$.

Example 3.2: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{< a, 0.5, 0.6, 0.3 > < b, 0.4, 0.2, 0.7 >\}$ and $M = \{< a, 0.5, 0.7, 0.6 > < b, 0.2, 0.4, 0.4 >\}$. Consider the collection $\mathcal{A} = \{A: A \subset M, A \not\subset M^c, M^c \not\subset A\}$ of neutrosophic sets in U . Then $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, 1_{N_{tr}}\}$.





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Definition 3.3: A Neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophicpre*-open if $K \subseteq N_{tr}int^*(N_{tr}cl(K))$.

Example 3.4: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.6, 0.8 \rangle \langle b, 0.6, 0.8, 0.9 \rangle \}$ and $M = \{ \langle a, 0.6, 0.4, 0.9 \rangle \langle b, 0.2, 0.4, 0.4 \rangle \}$. Consider the collection $\mathcal{A} = \{A: M \subset A, M^C \subset A\}$ and $\mathcal{B} = \{A: B \subset M, B^C \subset M\}$ of neutrosophic sets in U . Then $N_{tr}P^*O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$.

Definition 3.5: A neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophic Λ_P -open if there exist a N_{tr} pre*-open set $E \neq 0_{N_{tr}}, 1_{N_{tr}}$ such that $K \subseteq N_{tr}cl(K \cap E)$.

Example 3.6: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.5, 0.1 \rangle \langle b, 0.3, 0.8, 0.1 \rangle \}$ and $M = \{ \langle a, 0.9, 0.7, 0.2 \rangle \langle b, 0.4, 0.8, 0.1 \rangle \}$. Consider the collection $\mathcal{A} = \{A: 0_{N_{tr}} \subset A \subset K^C\}$, $\mathcal{B} = \{B: K^C \subset B \subset K\}$, $\mathcal{C} = \{C: K \subset C \subset 1_{N_{tr}}\}$ and $\mathcal{D} = \{D: D \not\subset K^C; K^C \not\subset D; D \subset K\}$ of neutrosophic sets in U . Then $N_{tr}\Lambda_P^*O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, M^C, \mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{D}, 1_{N_{tr}}\}$.

Theorem 3.7: Every N_{tr} pre-open is N_{tr} pre*-open.

Proof: Let K be a N_{tr} pre-open set in U . Then $K \subseteq N_{tr}int(N_{tr}cl(K)) \subseteq N_{tr}int^*(N_{tr}cl(K))$. Hence K is N_{tr} pre*-open.

Remark 3.8: In any neutrosophic topological space $(U, \tau_{N_{tr}})$, $0_{N_{tr}}$ and $1_{N_{tr}}$ are $N_{tr}\Lambda_P$ -open.

Theorem 3.9: The union of an arbitrary collection of $N_{tr}\Lambda_P$ -open sets is also $N_{tr}\Lambda_P$ -open.

Proof: Let $\{K_j: j \in J\}$ be a collection of $N_{tr}\Lambda_P$ -open sets. Then for each $j \in J$, K_j is a $N_{tr}\Lambda_P$ -open set which implies $K_j \subseteq N_{tr}cl(K_j \cap E)$. Now $\bigcup_{j \in J} K_j \subseteq \bigcup_{j \in J} N_{tr}cl(K_j \cap E) \subseteq N_{tr}cl(\bigcup_{j \in J} (K_j \cap E)) \subseteq N_{tr}cl(\bigcup_{j \in J} K_j \cap E)$. Thus $\bigcup_{j \in J} K_j \subseteq N_{tr}cl(\bigcup_{j \in J} K_j \cap E)$. Hence $\bigcup_{j \in J} K_j$ is a $N_{tr}\Lambda_P$ -open set.

Remark 3.10: The intersection of two $N_{tr}\Lambda_P$ -open sets need not be $N_{tr}\Lambda_P$ -open.

Example 3.13: Let $U = \{a, b\}$ and

$$K_1 = \{ \langle a, 0.5, 0.5, 0.4 \rangle \langle b, 0.4, 0.2, 0.6 \rangle \}$$

$$K_2 = \{ \langle a, 0.2, 0.3, 0.7 \rangle \langle b, 0.4, 0.1, 0.8 \rangle \}$$

$$K_3 = \{ \langle a, 0.4, 0.5, 0.5 \rangle \langle b, 0.3, 0.2, 0.8 \rangle \}$$

$$K_4 = \{ \langle a, 0.6, 0.6, 0.2 \rangle \langle b, 0.4, 0.2, 0.6 \rangle \}$$

$$K_5 = \{ \langle a, 0.5, 0.5, 0.4 \rangle \langle b, 0.8, 0.8, 0.3 \rangle \}$$

$$K_6 = \{ \langle a, 0.7, 0.7, 0.2 \rangle \langle b, 0.8, 0.9, 0.4 \rangle \}$$

$$K_7 = \{ \langle a, 0.2, 0.4, 0.6 \rangle \langle b, 0.6, 0.8, 0.4 \rangle \}$$

$$K_8 = \{ \langle a, 0.4, 0.7, 0.2 \rangle \langle b, 0.4, 0.7, 0.3 \rangle \}$$

$$K_9 = \{ \langle a, 0.2, 0.4, 0.6 \rangle \langle b, 0.4, 0.7, 0.4 \rangle \}$$
 be neutrosophic sets in U .

Then $\tau_{N_{tr}} = \{0_{N_{tr}}, K_1, K_2, K_3, K_4, K_5, 1_{N_{tr}}\}$ forms a neutrosophic topology on U . Here K_7 and K_8 are $N_{tr}\Lambda_P$ -open but their intersection K_9 is not $N_{tr}\Lambda_P$ -open.

Remark 3.11: The class of $N_{tr}\Lambda_P$ -open sets does not form a topology on U .

Theorem 3.12: A neutrosophic set K in a neutrosophic topological space $(U, \tau_{N_{tr}})$ is $N_{tr}\Lambda_P$ -open if and only if for every neutrosophic point $u_{a,b,c} \in K$, there exists a $N_{tr}\Lambda_P$ -open set $M_{u_{a,b,c}}$ such that $u_{a,b,c} \in M_{u_{a,b,c}} \subseteq K$.

Proof: If K is $N_{tr}\Lambda_P$ -open then we may consider $M_{u_{a,b,c}} = K$ for every $u_{a,b,c} \in K$. Conversely, assume that for every $u_{a,b,c} \in K$, there exists a $N_{tr}\Lambda_P$ -open set $M_{u_{a,b,c}}$ such that $u_{a,b,c} \in M_{u_{a,b,c}} \subseteq K$. Then, $K = \bigcup \{u_{a,b,c} : u_{a,b,c} \in K\} \subseteq \bigcup \{M_{u_{a,b,c}} : u_{a,b,c} \in K\} \subseteq K$. Hence, by theorem 3.9, $K = \bigcup \{M_{u_{a,b,c}} : u_{a,b,c} \in K\}$ is $N_{tr}\Lambda_P$ -open.

Theorem 3.13: Every N_{tr} -open set is $N_{tr}\Lambda_P$ -open.

Proof: Let K be a N_{tr} -open set in U . Then $K = N_{tr}int(K) = K \cap N_{tr}int(K) \subseteq N_{tr}cl(K \cap N_{tr}int(K))$. Take $E = N_{tr}int(K)$ then E is a N_{tr} -open set in U . By remark 2.12(i), E is N_{tr} pre-open. Thus $K \subseteq N_{tr}cl(K) \subseteq N_{tr}cl(K \cap E)$ for some N_{tr} pre-open set $E \neq 0_{N_{tr}}, 1_{N_{tr}}$. Hence K is $N_{tr}\Lambda_P$ -open.





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Remark 3.14: The converse of the above theorem need not be true.

Example 3.15: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.6, 0.2 \rangle < b, 0.3, 0.8, 0.1 \rangle \}$ and $M = \{ \langle a, 0.8, 0.7, 0.1 \rangle < b, 0.4, 0.9, 0 \rangle \}$. Consider the collection $\mathcal{A} = \{A: K^C \subset A \subset K\}$ and $\mathcal{B} = \{B: K^C \subset B \not\subset K\}$ of neutrosophic sets in U . Then $N_{tr}O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$. Here the neutrosophic sets in \mathcal{B} are $N_{tr}\Lambda_P$ -open but not N_{tr} -open.

Theorem 3.16: Every N_{tr} regular-open set is $N_{tr}\Lambda_P$ -open.

Proof: Let K be a N_{tr} regular-open set in U . By remark 2.12(ii), and by theorem 3.13, K is $N_{tr}\Lambda_P$ -open.

Remark 3.17: The converse of the above theorem need not be true.

Example 3.18: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.6, 0.8 \rangle < b, 0.6, 0.8, 0.9 \rangle \}$ and $M = \{ \langle a, 0.6, 0.4, 0.9 \rangle < b, 0.5, 0.7, 0.1 \rangle \}$. Consider the collection $\mathcal{A} = \{A: K \subset A; K^C \subset A\}$ and $\mathcal{B} = \{B: B \subset K; B \subset K^C\}$ of neutrosophic sets in U . Then $N_{tr}rO(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$. Here, K, M and the neutrosophic sets in \mathcal{A} and \mathcal{B} are $N_{tr}\Lambda_P$ -open but not N_{tr} regular-open.

Theorem 3.19: Every $N_{tr}\delta$ -open set is $N_{tr}\Lambda_P$ -open.

Proof: Let K be a $N_{tr}\delta$ -open set in U . By remark 2.12(iii) and by theorem 3.13, K is $N_{tr}\Lambda_P$ -open.

Remark 3.20: The converse of the above theorem need not be true.

Example 3.21: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.6, 0.8 \rangle < b, 0.6, 0.8, 0.9 \rangle \}$ and $M = \{ \langle a, 0.6, 0.4, 0.9 \rangle < b, 0.5, 0.7, 0.1 \rangle \}$. Consider the collection $\mathcal{A} = \{A: K \subset A; K^C \subset A\}$ and $\mathcal{B} = \{B: B \subset K; B \subset K^C\}$ of neutrosophic sets in U . Then $N_{tr}\delta O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$. Here, K, M and the neutrosophic sets in \mathcal{A} and \mathcal{B} are $N_{tr}\Lambda_P$ -open but not $N_{tr}\delta$ -open.

Theorem 3.22: Every N_{tr} semi-open set is $N_{tr}\Lambda_P$ -open.

Proof: Let K be a N_{tr} semi-open set in U . By definition 2.6(i), there exists a N_{tr} open set $E \subseteq K \subseteq N_{tr}cl(E)$. Since $E \subseteq K$, $K \cap E = E$. Hence $K \subseteq N_{tr}cl(K \cap E)$. Hence by remark 2.9(i), K is $N_{tr}\Lambda_P$ -open.

Remark 3.23: The converse of the above theorem need not be true.

Example 3.24: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.8, 0.9 \rangle < b, 0.7, 0.8, 0.9 \rangle \}$ and $M = \{ \langle a, 0.8, 0.9, 0.6 \rangle < b, 0.7, 0.8, 0.9 \rangle \}$. Consider the collection $\mathcal{A} = \{A: K \subset A; K^C \subset A\}$ and $\mathcal{B} = \{B: B \subset K; B \not\subset K^C; K^C \not\subset B\}$ of neutrosophic sets in U . Then $N_{tr}SO(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{B}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, M^C, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$. Here K^C, M^C and the neutrosophic sets in \mathcal{A} are $N_{tr}\Lambda_P$ -open but not N_{tr} semi-open.

Theorem 3.25: Every $N_{tr}\alpha$ -open set is $N_{tr}\Lambda_P$ -open.

Proof: Let K be a $N_{tr}\alpha$ -open set. Then $K \subseteq N_{tr}int(N_{tr}cl(N_{tr}int(K))) \subseteq N_{tr}cl(N_{tr}int(K))$. Thus K is N_{tr} semi-open. By theorem 3.21, K is $N_{tr}\Lambda_P$ -open.

Remark 3.26: The converse of the above theorem need not be true.

Example 3.27: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.3, 0.4, 0.9 \rangle < b, 0.4, 0.5, 0.8 \rangle \}$ and $M = \{ \langle a, 0.2, 0.3, 1 \rangle < b, 0.3, 0.4, 0.9 \rangle \}$. Consider the collection $\mathcal{A} = \{A: 0_{N_{tr}} \subset A \subset K\}$ and $\mathcal{B} = \{B: K \subset B \subset K^C\}$ of neutrosophic sets in U . Then $N_{tr}\alpha O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, M^C, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$. Here, K^C, M^C and the neutrosophic sets in \mathcal{A} and \mathcal{B} are $N_{tr}\Lambda_P$ -open but not $N_{tr}\alpha$ -open.

Theorem 3.28: Every $N_{tr}\Lambda_P$ -open set is $N_{tr}\Lambda_P^*$ -open.

Proof: Let K be a $N_{tr}\Lambda_P$ -open set in U . Then there exists a N_{tr} pre-open set $E \neq 0_{N_{tr}}, 1_{N_{tr}}$ such that $K \subseteq N_{tr}cl(K \cap E)$. Hence by theorem 3.7, K is $N_{tr}\Lambda_P^*$ -open.

Remark 3.29: The converse of the above theorem need not be true.

Example 3.30: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.7, 0.6, 0.8 \rangle < b, 0.6, 0.8, 0.9 \rangle \}$ and $M = \{ \langle a, 0.6, 0.4, 0.9 \rangle < b, 0.2, 0.4, 0.4 \rangle \}$. Consider the collection $\mathcal{A} = \{A: M \subset A, M^C \subset A\}$ and $\mathcal{B} = \{A: B \subset M, B^C \subset M\}$ of neutrosophic sets in U . Then





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$N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P^* O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$. Here K^C is $N_{tr}\Lambda_P^*$ -open but not $N_{tr}\Lambda_P$ -open.

Theorem 3.31: In any neutrosophic topological space $(U, \tau_{N_{tr}})$, $N_{tr}O(U, \tau_{N_{tr}}) \subseteq N_{tr}i\Lambda_P O(U, \tau_{N_{tr}}) \subseteq N_{tr}\Lambda_P^* O(U, \tau_{N_{tr}})$. That is the class of $N_{tr}\Lambda_P$ -open sets lie between N_{tr} -open sets and $N_{tr}\Lambda_P^*$ -open sets.

Proof: Proof follows from theorem 3.13 and theorem 3.28.

Remark 3.32: The concepts of N_{tr} b-open and $N_{tr}\Lambda_P$ -open are independent.

Example 3.33: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{< a, 0.4, 0.5, 0.6 > < b, 0.6, 0.3, 0.8 >\}$ and $M = \{< a, 0.3, 0.4, 0.7 > < b, 0.5, 0.2, 0.9 >\}$. Consider the collection $\mathcal{A} = \{A: K^C \subset A \subset 1_{N_{tr}}\}$ and $\mathcal{B} = \{B: K \subset B \not\subset K^C\}$ of neutrosophic sets in U . Then $N_{tr}bO(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, M^C, \mathcal{B}, 1_{N_{tr}}\}$. Here, the neutrosophic sets in \mathcal{A} are N_{tr} b-open but not $N_{tr}\Lambda_P$ -open and M^C is $N_{tr}\Lambda_P$ -open but not N_{tr} b-open.

Remark 3.34: The concepts of $N_{tr}Y$ -open and $N_{tr}\Lambda_P$ -open are independent.

Example 3.35: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{< a, 0.3, 0.4, 0.9 > < b, 0.4, 0.5, 0.8 >\}$ and $M = \{< a, 0.2, 0.3, 1 > < b, 0.3, 0.4, 0.9 >\}$. Consider the collection $\mathcal{A} = \{A: 0_{N_{tr}} \subset A \subset K\}$, $\mathcal{B} = \{B: K \subset B \subset K^C\}$, $\mathcal{C} = \{K^C \subset C \subset 1_{N_{tr}}\}$, $\mathcal{D} = \{D \not\subset K; K \not\subset D; D \subset K^C\}$, $\mathcal{E} = \{E \not\subset K; K \not\subset E; E \subset K^C\}$ and $\mathcal{F} = \{K \subset F \not\subset K^C\}$ of neutrosophic sets in U . Then $N_{tr}YO(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, \mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{F}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, M^C, \mathcal{A}, \mathcal{D}, \mathcal{E}, \mathcal{F}, 1_{N_{tr}}\}$. Here, the neutrosophic sets in \mathcal{B} and \mathcal{C} are $N_{tr}Y$ -open but not $N_{tr}\Lambda_P$ -open and the neutrosophic sets in \mathcal{D}, \mathcal{E} and M^C are $N_{tr}\Lambda_P$ -open but not $N_{tr}Y$ -open.

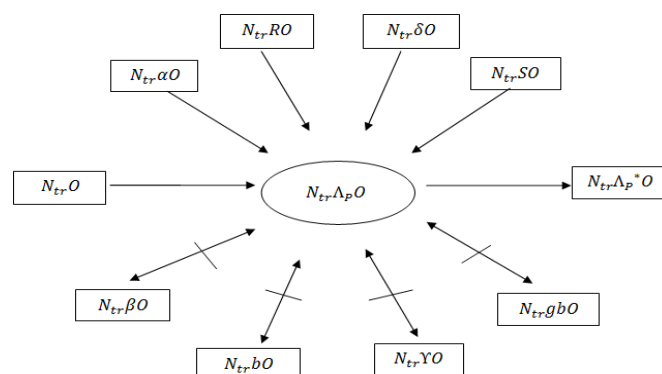
Remark 3.36: The concepts of $N_{tr}gb$ -open and $N_{tr}\Lambda_P$ -open are independent.

Example 3.37: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, 1_{N_{tr}}\}$ where $K = \{< a, 0.5, 0.6, 0.3 > < b, 0.4, 0.2, 0.7 >\}$. Consider the collection $\mathcal{A} = \{A: A \subset K; A \subset K^C\}$ and $\mathcal{B} = \{B: B \subset K; B \subset K^C; K^C \not\subset B\}$, $\mathcal{C} = \{K \subset C; C \subset K^C; K^C \not\subset C\}$, $\mathcal{D} = \{K \not\subset D; D \not\subset K; K^C \subset D\}$, $\mathcal{E} = \{K \subset E; K^C \subset E\}$, $\mathcal{F} = \{F \not\subset K; K \not\subset F; F \subset K^C\}$ and $\mathcal{G} = \{G \not\subset K; K \not\subset G; G \subset K^C; K^C \not\subset G\}$ of neutrosophic sets in U . Then $N_{tr}gbO(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, \mathcal{B}, \mathcal{C}, \mathcal{D}, \mathcal{E}, \mathcal{G}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, K^C, \mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{D}, \mathcal{E}, \mathcal{F}, 1_{N_{tr}}\}$. Here, the neutrosophic sets in \mathcal{G} are $N_{tr}gb$ -open but not $N_{tr}\Lambda_P$ -open and the neutrosophic sets in \mathcal{A}, \mathcal{F} and K^C are $N_{tr}\Lambda_P$ -open but not $N_{tr}gb$ -open.

Remark 3.38: The concepts of $N_{tr}\beta$ -open and $N_{tr}\Lambda_P$ -open are independent.

Example 3.39: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{< a, 0.4, 0.2, 0.7 > < b, 0.5, 0.6, 0.3 >\}$ and $M = \{< a, 0.2, 0.3, 1 > < b, 0.3, 0.4, 0.9 >\}$. Consider the collection $\mathcal{A} = \{A: A \subset K; A \subset K^C\}$ and $\mathcal{B} = \{B: B \subset K; B \subset K^C; K^C \not\subset B\}$, $\mathcal{C} = \{K \subset C; C \subset K^C; K^C \not\subset C\}$, $\mathcal{D} = \{K \not\subset D; D \not\subset K; K^C \subset D\}$, $\mathcal{E} = \{K \subset E; K^C \subset E\}$, $\mathcal{F} = \{F \not\subset K; K \not\subset F; F \subset K^C\}$ and $\mathcal{G} = \{G \not\subset K; K \not\subset G; G \subset K^C; K^C \not\subset G\}$ of neutrosophic sets in U . Then $N_{tr}\beta O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, M^C, \mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{D}, \mathcal{E}, \mathcal{F}, \mathcal{G}, 1_{N_{tr}}\}$ and $N_{tr}\Lambda_P O(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, K^C, \mathcal{A}, \mathcal{B}, \mathcal{C}, \mathcal{E}, \mathcal{F}, 1_{N_{tr}}\}$. Here, the neutrosophic sets in \mathcal{D} and M^C are $N_{tr}\beta$ -open but not $N_{tr}\Lambda_P$ -open and the neutrosophic sets in \mathcal{F} are $N_{tr}\Lambda_P$ -open but not $N_{tr}\beta$ -open.

From the above discussion we have the following diagram:





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Theorem 3.40: Let K be a $N_{tr}\Lambda_P$ -open set and M be any neutrosophic set in U such that $K \subseteq M \subseteq N_{tr}cl(K)$. Then M is $N_{tr}\Lambda_P$ -open.

Proof: Since $K \subseteq M$, $K \cap E \subseteq M \cap E$ and hence $N_{tr}cl(K \cap E) \subseteq N_{tr}cl(M \cap E)$. Also, since $M \subseteq N_{tr}cl(K)$ and K is $N_{tr}\Lambda_P$ -open, $M \subseteq N_{tr}cl(N_{tr}cl(K \cap E)) \subseteq N_{tr}cl(K \cap E) \subseteq N_{tr}cl(M \cap E)$ for some N_{tr} -pre-open set $E \neq 0_{N_{tr}}, 1_{N_{tr}}$.

Theorem 3.41: If K is N_{tr} semi-open set and $K \subseteq E$, then $N_{tr}int(K)$ is $N_{tr}\Lambda_P$ -open.

Proof: Since K is N_{tr} semi-open and $K \subseteq E$, we have $K \subseteq N_{tr}cl(N_{tr}int(K))$ which implies $N_{tr}int(K) \subseteq N_{tr}int(N_{tr}cl(N_{tr}int(K))) \subseteq N_{tr}int(N_{tr}cl(N_{tr}int(K \cap E))) \subseteq N_{tr}cl((N_{tr}int(K)) \cap E)$ for some N_{tr} -pre-open set $E \neq 0_{N_{tr}}, 1_{N_{tr}}$. Hence $N_{tr}int(K)$ is $N_{tr}\Lambda_P$ -open.

Theorem 3.42: If $E = N_{tr}pint(K)$, then every $N_{tr}\Lambda_P$ -open set is $N_{tr}\beta$ -open.

Proof: Let K be a $N_{tr}\Lambda_P$ -open set and let $E = N_{tr}pint(K)$. Since K is $N_{tr}\Lambda_P$ -open, $K \subseteq N_{tr}cl(K \cap E) \subseteq N_{tr}cl(K \cap N_{tr}pint(K)) \subseteq N_{tr}cl(K \cap (K \cap N_{tr}int(N_{tr}cl(K)))) \subseteq N_{tr}cl(K \cap N_{tr}int(N_{tr}cl(K))) \subseteq N_{tr}cl(K) \cap N_{tr}cl(N_{tr}int(N_{tr}cl(K))) \subseteq N_{tr}cl(N_{tr}int(N_{tr}cl(K)))$. Thus $K \subseteq N_{tr}cl(N_{tr}int(N_{tr}cl(K)))$. Hence K is $N_{tr}\beta$ -open.

4. Neutrosophic Λ_P -Closed Sets

Definition 4.1: A neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$ is said to be neutrosophic Λ_P -closed if there exist a N_{tr} -pre-closed set $F \neq 0_{N_{tr}}, 1_{N_{tr}}$ such that $N_{tr}int(K \cup F) \subseteq K$. The class of neutrosophic Λ_P -closed sets is denoted by $N_{tr}\Lambda_P C(U, \tau_{N_{tr}})$.

Example 4.2: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, M, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.4, 0.6, 0.8 \rangle, \langle b, 0.1, 0.3, 0.5 \rangle \}$ and $M = \{ \langle a, 0.5, 0.7, 0.6 \rangle, \langle b, 0.2, 0.4, 0.4 \rangle \}$. Consider the collection $\mathcal{A} = \{A: A \subset M; A \not\subset M^c; M^c \not\subset A\}$ and $\mathcal{B} = \{B: B \not\subset M; M \not\subset B^c; B \subset M^c\}$ of neutrosophic sets in U . Then $N_{tr}\Lambda_P C(U, \tau_{N_{tr}}) = \{0_{N_{tr}}, K, M, \mathcal{A}, \mathcal{B}, 1_{N_{tr}}\}$.

Theorem 4.3: In any neutrosophic topological space $(U, \tau_{N_{tr}})$,

- Every N_{tr} -closed set is $N_{tr}\Lambda_P$ -closed.
- Every N_{tr} regular-closed set is $N_{tr}\Lambda_P$ -closed.
- Every $N_{tr}\delta$ -closed set is $N_{tr}\Lambda_P$ -closed.
- Every N_{tr} semi-closed set is $N_{tr}\Lambda_P$ -closed.
- Every $N_{tr}\alpha$ -closed set is $N_{tr}\Lambda_P$ -closed.
- Every $N_{tr}\Lambda_P$ -closed set is $N_{tr}\Lambda_P^*$ -closed.

Proof: Proof is obvious.

Remark 4.4: The converse of each of the statements of the above theorem need not be true.

Remark 4.5:

- The union of any two $N_{tr}\Lambda_P$ -closed sets need not be $N_{tr}\Lambda_P$ -closed.
- The intersection of an arbitrary collection $N_{tr}\Lambda_P$ -closed set is $N_{tr}\Lambda_P$ -closed.
- The concepts of $N_{tr}\beta$ -closed and $N_{tr}\Lambda_P$ -closed are independent.
- The concepts of $N_{tr}\gamma$ -closed and $N_{tr}\Lambda_P$ -closed are independent.
- The concepts of $N_{tr}gb$ -closed and $N_{tr}\Lambda_P$ -closed are independent.
- The concepts of $N_{tr}\beta$ -closed and $N_{tr}\Lambda_P$ -closed are independent.
- The class of $N_{tr}\Lambda_P$ -closed sets lie between N_{tr} -closed sets and $N_{tr}\Lambda_P^*$ -closed sets.

5. Neutrosophic Λ_P -Operators

Definition 5.1: Let $(U, \tau_{N_{tr}})$ be a neutrosophic topological space and K be a neutrosophic set in U .

- The neutrosophic Λ_P -interior of K is the union of all $N_{tr}\Lambda_P$ -open sets contained in K . It is denoted by $N_{tr}\Lambda_P int(K)$.
- The neutrosophic Λ_P -closure of K is the intersection of all $N_{tr}\Lambda_P$ -closed sets containing K . It is denoted by $N_{tr}\Lambda_P cl(K)$.





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Remark 5.2:

- i. $N_{tr}\Lambda_P int(K)$ is the largest $N_{tr}\Lambda_P$ -open set contained in K .
- ii. $N_{tr}\Lambda_P cl(K)$ is the smallest $N_{tr}\Lambda_P$ -closed set containing K .

Theorem 5.3: Let K be a neutrosophic set of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then,

- i. K is $N_{tr}\Lambda_P$ -open if and only if $N_{tr}\Lambda_P int(K) = K$.
- ii. K is $N_{tr}\Lambda_P$ -closed if and only if $N_{tr}\Lambda_P cl(K) = K$.

Proof:

- i. Suppose K is $N_{tr}\Lambda_P$ -open. Then by definition 5.1(i), it is obvious that $N_{tr}\Lambda_P int(K) = K$. Conversely, suppose $N_{tr}\Lambda_P int(K) = K$. Then, by remark 5.2(i), $N_{tr}\Lambda_P int(K)$ is $N_{tr}\Lambda_P$ -open and hence K is $N_{tr}\Lambda_P$ -open.
- ii. The proof is similar to (i).

Theorem 5.4: Let $(U, \tau_{N_{tr}})$ be a neutrosophic topological space and K, M be neutrosophic sets in U . Then

- i. $N_{tr}\Lambda_P int(0_{N_{tr}}) = 0_{N_{tr}}$ and $N_{tr}\Lambda_P int(1_{N_{tr}}) = 1_{N_{tr}}$
- ii. $K \subseteq M \Rightarrow N_{tr}\Lambda_P int(K) \subseteq N_{tr}\Lambda_P int(M)$
- iii. $N_{tr}\Lambda_P int(N_{tr}\Lambda_P int(K)) = N_{tr}\Lambda_P int(K)$
- iv. $N_{tr}\Lambda_P int(K \cup M) \supseteq N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P int(M)$
- v. $N_{tr}\Lambda_P int(K \cap M) \subseteq N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P int(M)$

Proof:

- i. $0_{N_{tr}}$ and $1_{N_{tr}}$ are $N_{tr}\Lambda_P$ -open sets. Hence by theorem 5.3(i), $N_{tr}\Lambda_P int(0_{N_{tr}}) = 0_{N_{tr}}$ and $N_{tr}\Lambda_P int(1_{N_{tr}}) = 1_{N_{tr}}$.
- ii. By remark 5.2(i) that $N_{tr}\Lambda_P int(K) \subseteq K$ and $N_{tr}\Lambda_P int(M) \subseteq M$. Now $N_{tr}\Lambda_P int(K) \subseteq K \subseteq M$ implies $N_{tr}\Lambda_P int(K) \subseteq M$. Since $N_{tr}\Lambda_P int(M)$ is the largest $N_{tr}\Lambda_P$ -open set contained in M , we have $N_{tr}\Lambda_P int(K) \subseteq N_{tr}\Lambda_P int(M)$.
- iii. By remark 5.2(i), $N_{tr}\Lambda_P int(K)$ is $N_{tr}\Lambda_P$ -open. Then by above theorem, $N_{tr}\Lambda_P int(N_{tr}\Lambda_P int(K)) = N_{tr}\Lambda_P int(K)$.
- iv. Since $K \subseteq K \cup M$, it follows from (iii) that $N_{tr}\Lambda_P int(K) \subseteq N_{tr}\Lambda_P int(K \cup M)$. Similarly, $N_{tr}\Lambda_P int(M) \subseteq N_{tr}\Lambda_P int(K \cup M)$. Thus $N_{tr}\Lambda_P int(K \cup M) \supseteq N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P int(M)$.
- v. Since $K \cap M \subseteq K$, it follows from (iii) that $N_{tr}\Lambda_P int(K \cap M) \subseteq N_{tr}\Lambda_P int(K)$. Similarly, $N_{tr}\Lambda_P int(K \cap M) \subseteq N_{tr}\Lambda_P int(M)$. Thus $N_{tr}\Lambda_P int(K \cap M) \subseteq N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P int(M)$.

Remark 5.5: The above theorem is true for neutrosophic Λ_P -closure.

Theorem 5.6: For any neutrosophic set K of a neutrosophic topological space $(U, \tau_{N_{tr}})$,

- i. $(N_{tr}\Lambda_P int(K))^C = N_{tr}\Lambda_P cl(K^C)$
- ii. $(N_{tr}\Lambda_P cl(K))^C = N_{tr}\Lambda_P int(K^C)$

Proof:

$$\begin{aligned} \text{i. } (N_{tr}\Lambda_P int(K))^C &= (\cup \{M: M \subseteq K \text{ and } M \in N_{tr}\Lambda_P O(U, \tau_{N_{tr}})\})^C \\ &= \cap \{M^C: K^C \subseteq M^C \text{ and } M^C \in N_{tr}\Lambda_P C(U, \tau_{N_{tr}})\} \\ &= N_{tr}\Lambda_P cl(K^C) \end{aligned}$$

- ii. The proof is similar to (i).

Definition 5.7: Let K be a neutrosophic subset of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then the neutrosophic Λ_P -Frontier of K is defined as $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(K^C)$. Obviously $N_{tr}\Lambda_P Fr(K)$ is a $N_{tr}\Lambda_P$ -closed set in $(U, \tau_{N_{tr}})$.

Example 5.8: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, 1_{N_{tr}}\}$ where $K = \{ \langle a, 0.2, 0.4, 0.4 \rangle, \langle b, 0.8, 0.6, 0.6 \rangle \}$ and $K^C = \{ \langle a, 0.4, 0.6, 0.2 \rangle, \langle b, 0.6, 0.4, 0.8 \rangle \}$. Consider the collection $\mathcal{A} = \{A: A \subseteq K, A \not\subseteq K^C, K^C \not\subseteq A\}$ and $\mathcal{B} = \{B: K^C \subseteq B \not\subseteq K\}$ of neutrosophic sets in U . Then $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(K^C) = 1_{N_{tr}} \cap K^C = K^C$. Thus $N_{tr}\Lambda_P Fr(K) = \{ \langle a, 0.4, 0.6, 0.2 \rangle, \langle b, 0.6, 0.4, 0.8 \rangle \}$.





Definition 5.9: Let K be a neutrosophic subset of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then the neutrosophic Λ_P -Border of K is denoted as $N_{tr}\Lambda_P Br(K)$ and is defined as $N_{tr}\Lambda_P Br(K) = K - N_{tr}\Lambda_P int(K)$. (Equivalently, $N_{tr}\Lambda_P Br(K) = K \cap N_{tr}\Lambda_P int(K)$).

Example 5.10: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, 1_{N_{tr}}\}$ where $K = \{< a, 0.3, 0.4, 0.9 > < b, 0.4, 0.5, 0.8 >\}$ and $K^c = \{< a, 0.9, 0.6, 0.3 > < b, 0.8, 0.5, 0.4 >\}$. Consider the collection $\mathcal{A} = \{A: K \subset A \subset K^c\}$ and $\mathcal{B} = \{B: K^c \subset B \subset 1_{N_{tr}}\}$ of neutrosophic sets in U . Then $N_{tr}\Lambda_P Br(K) = K \cap N_{tr}\Lambda_P int(K) = K \cap K = K$. Thus $N_{tr}\Lambda_P Br(K) = \{< a, 0.3, 0.4, 0.9 > < b, 0.4, 0.5, 0.8 >\}$.

Definition 5.11: Let K be a neutrosophic subset of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then the neutrosophic Λ_P -Exterior of K is denoted as $N_{tr}\Lambda_P Ext(K)$ and is defined as $N_{tr}\Lambda_P Ext(K) = N_{tr}\Lambda_P int(K^c)$. (Equivalently, $N_{tr}\Lambda_P Ext(K) = K - N_{tr}\Lambda_P int(K)$).

Example 5.12: Let $U = \{a, b\}$ and $\tau_{N_{tr}} = \{0_{N_{tr}}, K, 1_{N_{tr}}\}$ where $K = \{< a, 0.5, 0.2, 0.9 > < b, 0.2, 0.4, 0.6 >\}$ and $K^c = \{< a, 0.9, 0.8, 0.5 > < b, 0.6, 0.6, 0.2 >\}$. Consider the collection $\mathcal{A} = \{A: K \subset A \not\subset K^c\}$ and $\mathcal{B} = \{B: K^c \subset B \subset 1_{N_{tr}}\}$ of neutrosophic sets in U . Then $N_{tr}\Lambda_P Ext(K) = N_{tr}\Lambda_P int(K^c) = \mathcal{B}$. Thus $N_{tr}\Lambda_P Ext(K) = \{< a, 0.3, 0.1, 1 > < b, 0.1, 0.3, 0.7 >\}$.

Theorem 5.13: Let K be a neutrosophic set of a neutrosophic topological space $(U, \tau_{N_{tr}})$. Then, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) - N_{tr}\Lambda_P int(K)$.

Proof: Let K be a neutrosophic set in $(U, \tau_{N_{tr}})$. By definition 5.7, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(K^c)$ and by theorem 5.6, $(N_{tr}\Lambda_P int(K))^c = N_{tr}\Lambda_P cl(K^c)$. Now $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) \cap (N_{tr}\Lambda_P int(K))^c$. Hence by known result $[A - B = A \cap B^c]$, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) - N_{tr}\Lambda_P int(K)$.

Theorem 5.14: For a neutrosophic subset K of a neutrosophic topological space $(U, \tau_{N_{tr}})$, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P Fr(K^c)$.

Proof: Let K be a neutrosophic subset in $(U, \tau_{N_{tr}})$. By definition 5.7, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(K^c) = N_{tr}\Lambda_P cl(K^c) \cap N_{tr}\Lambda_P cl((K^c)^c) = N_{tr}\Lambda_P Fr(K^c)$. Hence $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P Fr(K^c)$.

Theorem 5.15: A neutrosophic subset K is $N_{tr}\Lambda_P$ -closed in $(U, \tau_{N_{tr}})$ if and only if $N_{tr}\Lambda_P Fr(K) \subseteq K$.

Proof: Let K be $N_{tr}\Lambda_P$ -closed in U . By definition 5.7, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(K^c) \subseteq N_{tr}\Lambda_P cl(K)$. By theorem, $N_{tr}\Lambda_P cl(K) = K$. Hence $N_{tr}\Lambda_P Fr(K) \subseteq K$ if K is $N_{tr}\Lambda_P$ -closed in U . Conversely, let $N_{tr}\Lambda_P Fr(K) \subseteq K$. Then $N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(K^c) \subseteq K$. Since $N_{tr}\Lambda_P int(K) \subseteq K$. Thus $N_{tr}\Lambda_P cl(K) = K$. Hence K is $N_{tr}\Lambda_P$ -closed.

Theorem 5.16: Let K and M be neutrosophic subsets in the neutrosophic topological space $(U, \tau_{N_{tr}})$. Then $N_{tr}\Lambda_P Fr(K \cap M) \subseteq N_{tr}\Lambda_P Fr(K) \cup N_{tr}\Lambda_P Fr(M)$.

Proof: By definition 5.7,

$$\begin{aligned} N_{tr}\Lambda_P Fr(K \cap M) &= N_{tr}\Lambda_P cl(K \cap M) \cap N_{tr}\Lambda_P cl(K \cap M)^c \\ &\subseteq (N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(M)) \cap (N_{tr}\Lambda_P cl(K^c) \cup N_{tr}\Lambda_P cl(M^c)) \\ &= \{(N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(M)) \cap N_{tr}\Lambda_P cl(K^c)\} \cup \{(N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P cl(M)) \cap N_{tr}\Lambda_P cl(M^c)\} \\ &= (N_{tr}\Lambda_P Fr(K) \cap N_{tr}\Lambda_P cl(M)) \cup (N_{tr}\Lambda_P cl(K) \cap N_{tr}\Lambda_P Fr(M)) \end{aligned}$$

$$\subseteq N_{tr}\Lambda_P Fr(K) \cup N_{tr}\Lambda_P Fr(M).$$

Hence $N_{tr}\Lambda_P Fr(K \cap M) \subseteq N_{tr}\Lambda_P Fr(K) \cup N_{tr}\Lambda_P Fr(M)$.

Theorem 5.17: For neutrosophic subset K of $(U, \tau_{N_{tr}})$, $N_{tr}\Lambda_P Br(K) = K \cap N_{tr}\Lambda_P cl(K^c)$.

Proof: By definition 5.9, $N_{tr}\Lambda_P Br(K) = K - N_{tr}\Lambda_P int(K)$ which implies $N_{tr}\Lambda_P Br(K) = K - (N_{tr}\Lambda_P cl(K^c))^c = K \cap N_{tr}\Lambda_P cl(K^c)$.

Theorem 5.18: For a neutrosophic subset K of a neutrosophic topological space $(U, \tau_{N_{tr}})$, $N_{tr}\Lambda_P Br(K) \subseteq N_{tr}\Lambda_P Fr(K)$.

Proof: Since $K \subseteq N_{tr}\Lambda_P cl(K)$, $K - N_{tr}\Lambda_P int(K) \subseteq N_{tr}\Lambda_P cl(K) - N_{tr}\Lambda_P int(K)$. This implies, $N_{tr}\Lambda_P Br(K) \subseteq N_{tr}\Lambda_P Fr(K)$.

Theorem 5.19: If K is $N_{tr}\Lambda_P$ -closed set in $(U, \tau_{N_{tr}})$, then $N_{tr}\Lambda_P Br(K) = N_{tr}\Lambda_P Fr(K)$.





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Proof: Let K be a $N_{tr}\Lambda_P$ -closed. Then by theorem 5.3, $N_{tr}\Lambda_P cl(K) = K$. Now by theorem 5.13, $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P cl(K) - N_{tr}\Lambda_P int(K) = K - N_{tr}\Lambda_P int(K) = N_{tr}\Lambda_P Br(K)$. Hence $N_{tr}\Lambda_P Fr(K) = N_{tr}\Lambda_P Br(K)$.

Theorem 5.20: For a neutrosophic subset K of a neutrosophic topological space $(U, \tau_{N_{tr}})$, then $K = N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P Br(K)$.

Proof: Let $u_{a,b,c} \in K$.

Case (i): If $u_{a,b,c} \in N_{tr}\Lambda_P int(K)$, then the result is obvious.

Case (ii): If $u_{a,b,c} \notin N_{tr}\Lambda_P int(K)$, then by the definition 5.9, $u_{a,b,c} \in N_{tr}\Lambda_P Br(K)$. Hence $u_{a,b,c} \in N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P Br(K)$ and so $K \subseteq N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P Br(K)$. On the otherhand, $N_{tr}\Lambda_P int(K) \subseteq K$ and $N_{tr}\Lambda_P Br(K) \subseteq K$. Thus we have $N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P Br(K) \subseteq K$. Hence $K = N_{tr}\Lambda_P int(K) \cup N_{tr}\Lambda_P Br(K)$.

Theorem 5.21: For a neutrosophic subset K of $(U, \tau_{N_{tr}})$, $N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P Br(K) = 0_{N_{tr}}$.

Proof: Suppose $N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P Br(K) \neq 0_{N_{tr}}$. Let $u_{a,b,c} \in N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P Br(K)$. Then $u_{a,b,c} \in N_{tr}\Lambda_P int(K)$ and $u_{a,b,c} \in N_{tr}\Lambda_P Br(K)$. By definition 5.9, $u_{a,b,c} \in K$. But $u_{a,b,c} \in N_{tr}\Lambda_P int(K)$ which is a contradiction. Hence $N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P Br(K) = 0_{N_{tr}}$.

Theorem 5.22: For a neutrosophic subset K of $(U, \tau_{N_{tr}})$, K is $N_{tr}\Lambda_P$ -open if and only if $N_{tr}\Lambda_P Br(K) = 0_{N_{tr}}$.

Proof: Suppose K is $N_{tr}\Lambda_P$ -open. Then by theorem 5.3(i), $N_{tr}\Lambda_P int(K) = K$. Now $N_{tr}\Lambda_P Br(K) = K - N_{tr}\Lambda_P int(K) = K - K = 0_{N_{tr}}$.

Conversely, suppose $N_{tr}\Lambda_P Br(K) = 0_{N_{tr}}$ implies $K - N_{tr}\Lambda_P int(K) = 0_{N_{tr}}$. Thus $K = N_{tr}\Lambda_P int(K)$. By theorem 5.3(i), K is $N_{tr}\Lambda_P$ -open.

Theorem 5.23: For any neutrosophic subset K of $(U, \tau_{N_{tr}})$, the following conditions hold:

- i. $N_{tr}\Lambda_P Br(N_{tr}\Lambda_P int(K)) = 0_{N_{tr}}$.
- ii. $N_{tr}\Lambda_P int(N_{tr}\Lambda_P Br(K)) = 0_{N_{tr}}$.

Proof:

- i. By definition 5.9, $N_{tr}\Lambda_P Br(N_{tr}\Lambda_P int(K)) = N_{tr}\Lambda_P int(K) - N_{tr}\Lambda_P int(N_{tr}\Lambda_P int(K))$. By theorem 5.3(i), $N_{tr}\Lambda_P int(N_{tr}\Lambda_P int(K)) = N_{tr}\Lambda_P int(K)$. Hence $N_{tr}\Lambda_P Br(N_{tr}\Lambda_P int(K)) = 0_{N_{tr}}$.
- ii. Let $u_{a,b,c} \in N_{tr}\Lambda_P int(N_{tr}\Lambda_P Br(K))$. Since $N_{tr}\Lambda_P Br(K) \subseteq K$ which implies $N_{tr}\Lambda_P int(N_{tr}\Lambda_P Br(K)) \subseteq N_{tr}\Lambda_P int(K)$. Hence $u_{a,b,c} \in N_{tr}\Lambda_P int(K)$. Since $N_{tr}\Lambda_P int(N_{tr}\Lambda_P Br(K)) \subseteq N_{tr}\Lambda_P Br(K)$, $u_{a,b,c} \in N_{tr}\Lambda_P Br(K)$. Hence $u_{a,b,c} \in N_{tr}\Lambda_P int(K) \cap N_{tr}\Lambda_P Br(K)$, $u_{a,b,c} = 0_{N_{tr}}$.

Theorem 5.24: For a neutrosophic subset K of a neutrosophic topological space $(U, \tau_{N_{tr}})$,

- i. $N_{tr}\Lambda_P Ext(K) = (N_{tr}\Lambda_P cl(K))^c$.
- ii. $N_{tr}\Lambda_P Ext(K) = N_{tr}\Lambda_P Ext((N_{tr}\Lambda_P Er(K))^c)$.
- iii. $N_{tr}\Lambda_P Ext(N_{tr}\Lambda_P Ext(K)) \supseteq N_{tr}\Lambda_P int(K)$.
- iv. $N_{tr}\Lambda_P Ext(K \cup M) \subseteq N_{tr}\Lambda_P Ext(K) \cap N_{tr}\Lambda_P Ext(M)$.
- v. $N_{tr}\Lambda_P Ext(K \cap M) \supseteq N_{tr}\Lambda_P Ext(K) \cup N_{tr}\Lambda_P Ext(M)$.

Proof:

- i. We know that $1_{N_{tr}} - N_{tr}\Lambda_P cl(K) = N_{tr}\Lambda_P int(K^c)$, then $N_{tr}\Lambda_P Ext(K) = N_{tr}\Lambda_P int(K^c) = (N_{tr}\Lambda_P cl(K))^c$.
- ii. $N_{tr}\Lambda_P Ext((N_{tr}\Lambda_P Er(K))^c) = N_{tr}\Lambda_P Ext((N_{tr}\Lambda_P int(K^c))^c) = N_{tr}\Lambda_P int((N_{tr}\Lambda_P int(K^c))^c) = N_{tr}\Lambda_P int(N_{tr}\Lambda_P int(K^c)) = N_{tr}\Lambda_P int(K^c) = N_{tr}\Lambda_P Ext(K)$.
- iii. $N_{tr}\Lambda_P Ext(N_{tr}\Lambda_P Ext(K)) = N_{tr}\Lambda_P Ext(N_{tr}\Lambda_P int(K^c)) = N_{tr}\Lambda_P int((N_{tr}\Lambda_P int(K^c))^c) = N_{tr}\Lambda_P int(N_{tr}\Lambda_P cl(K)) \supseteq N_{tr}\Lambda_P int(K)$.
- iv. $N_{tr}\Lambda_P Ext(K \cup M) = N_{tr}\Lambda_P int((K \cup M)^c) = N_{tr}\Lambda_P int((K^c) \cap (M^c)) \subseteq N_{tr}\Lambda_P int(K^c) \cap N_{tr}\Lambda_P int(M^c) = N_{tr}\Lambda_P Ext(K) \cap N_{tr}\Lambda_P Ext(M)$.





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$$v. \quad N_{tr}\Lambda_P Ext(K \cap M) = N_{tr}\Lambda_P int(K \cap M)^c = N_{tr}\Lambda_P int((K^c) \cup (M^c)) \subseteq N_{tr}\Lambda_P int(K^c) \cup N_{tr}\Lambda_P int(M^c) = N_{tr}\Lambda_P Ext(K) \cup N_{tr}\Lambda_P Ext(M).$$

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Nanomaterials Revolutionizing Psoriasis Treatment: Silver Nanoparticles from Medicinal Plant Extracts

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ABSTRACT

An autoimmune reaction results in hyper proliferative growths in Psoriasis vulgaris, the most common skin disorder. An inflammatory skin disease that produces redness and scaling, psoriasis produces inflammation in the skin. An overview of how a disease develops and progresses is related to the dysregulation of the innate immune system. A major area of nanotechnology that is growing rapidly is nanomaterials. In addition to reducing the time it takes, it eliminates the need for toxic chemicals. This study describes how silver nanoparticles (AgNPs) derived from a medicinal plant leaf extract can be used as a source of silver nanoparticles (AgNPs).

Keywords: Psoriasis Vulgaris, Autoimmune reaction, Hyper proliferative growths, Nanomaterials, Silver nanoparticles (AgNPs), Medicinal plant extract.

INTRODUCTION

Nanotechnology is an industry that is rapidly growing and is capable of creating nanoscale structures. Generally, nanoproducts are particles ranging in diameter from 1 to 100 nm and are created by the approach and synthesis of nanoparticles. Wet, dry, and computerized nanotechnology are all part of nanotechnology in living organisms. Membranes, organs, enzymes, and organelles are all part of wet nanotechnology. In dry nanotechnology, the production of inorganic materials like silicon and carbon is focused on surface science and physical and chemical properties. Computer nanotechnology involves modeling and simulating complex nanometre-scale structures [1]. To achieve optimal results, these three disciplines were integrated as shown in Figure 1. Nanoscale compounds have

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properties that allow them to be applied to a wide range of applications, while also extending the field of research on nanoscale materials. Bioremediation, pharmaceuticals, diagnostics, consumer goods, pharmaceutical supplements, growth inhibitors for biofilms, and biosensors are a few of the industries that use it[2]. A nanoparticle (NP) is a particle that has a minimum size of 100 nanometers [3]. Since they're not simple molecules, NPs have three layers: (1) An emulsifier, metal ion, or polymer can stabilize the surface layer. (2) Physically and chemically, the shell layer differs from the core. (3) There is a core element within the NP, which could be considered its central component. [4]. Because of the absorption in the visible region, NPs' optical properties are affected by their size. The size, shape, and structure of materials determine their reactivity and durability. NPs containing heavy metals, such as lead, mercury, and tin, pose a variety of environmental hazards as they are difficult to degrade [5]. Nanotechnology and biotechnology are combining to increase the focus on developing medical materials [6].The production of nanoparticles has been carried out using various plant parts, including fruits, leaves, stems, seeds, flowers, roots, bark, and rhizomes[7]. The physical, chemical, and biological properties of nanoparticles of silver (AgNPs) have recently been thoroughly investigated. Studies are currently being conducted to determine if AgNPs can be used in clinical and industrial applications, as well as in the development of drugs [8, 9].A dynamic metal, silver has excellent biological properties because at low concentrations, it can inhibit fungal, bacterial, viral, and infectious infections, heal wounds, and fight inflammation [10, 11].Silver, an inorganic antibacterial agent that is non-toxic, eliminates 650 types of disease-causing microorganisms [12, 13].Despite their increasing use in medicine and everyday life, AgNPs remain the subject of limited biomedical and toxicological studies [14, 15]. Patients' quality of life is negatively impacted by psoriasis, a chronic inflammatory skin condition. Recent research has suggested that psoriasis is a systemic disease caused by an impaired immune system. Numerous environmental factors, genetic factors, and immunological mechanisms contribute to the pathogenesis of psoriasis, as do pro-inflammatory cytokines. Current medications cause serious side effects, have high remission rates, and are resistant to chemotherapy. There is a strong need to produce safer and more effective treatment approaches based on the current treatment approaches [16, 17]. Due to their significant preventive activity against psoriasis, the plants can open the door to new therapeutic approaches [18]. Using conventional therapeutic approaches against psoriasis, the purpose of this paper is to indicate worthwhile prospects. Reviewing the literature related to herbal medicines that can effectively treat psoriasis was our primary objective. Psoriasis pathophysiology was discussed, as well as how plant products modulate pathophysiology. There is a summary of the scientific evidence that demonstrates the effectiveness of medicinal plants in treating psoriasis, along with their underlying mechanism of action.

Approaches of Nanoparticle Production

Physical, chemical, and biological approaches are currently used to synthesize AgNPs. AgNPs can be synthesized biologically and exhibit chemical and physical synthesis solubility, lack qualities such as high yield and stability are more labour-intensive and riskier [19, 20].Metallic nanoparticles are formulated using top-down and bottom-up approaches, as shown in Figure 2. Nanoparticles are synthesized via mechanical/ball milling, chemical etching, laser ablation, sputtering, condensation, and arc discharge [20, 21]. Biopolymers, microbes, and herbal extracts are involved in the biosynthesis of nanoparticles. Herbal remedies and drugs derived from plants have been extensively studied since ancient times. 8000 natural antibiotics with potent biological activities have been isolated, characterized, synthesized, and discovered as a result of pharmacological screening of natural source compounds. To make nanoparticles, chemical and physical processes are involved, resulting in high costs and health hazards for the environment. Creating nanoparticles involves several chemicals and physical processes, which are expensive and hazardous to the environment. Further, nanomaterials formed aggregates instead of particles. Biological AgNPs have been formed by bacteria, fungi, and plants [19]. AgNPs can be synthesized using biomolecules without harming the environment. There is a wide range of medical applications that can benefit from controlling particle size and shape through biological methods. Reducing agents such as bacterial proteins or plant extracts can indeed be used to control nanoparticle size, shape, and monodispersity. Additionally, biochemical methods provide a variety of natural resources, reduce production time requirements, and ensure high productivity. It is more effective and has superior properties to use nanoparticles with smaller sizes and shorter shapes. There are some drawbacks to synthesizing AgNPs of different shapes and sizes despite their success.By using biological synthesis methods, nanoparticles can be





controlled more easily in size, shape, and dispersion. It is possible to optimize the synthesis methods, including precursor number, pH, temperature, and stabilizing and reducing agents.

Psoriasis vulgaris

Skin epithelial cells constantly grow, resulting in the growth of raised, inflamed plaques with psoriasis vulgaris. While accurate statistics are difficult to obtain, it is estimated that psoriasis affects 1 to 3% of people worldwide. The pathophysiology of the disease is heavily influenced by genetic and cellular factors. The symptomatic treatments that are used as well as those that modulate the immune system respond to these different targets, so treatment strategies vary accordingly. In addition to environmental factors such as smoking, seasonal changes, and infections, it has also been determined that certain drugs may cause the disease. Conventional treatment has a detrimental effect on the quality of life, resulting in a search for natural alternatives. Traditional systems of medicine for psoriasis have utilized several plants that might act as safer alternatives to conventional therapies [23].

Medicinal plants having anti-psoriatic activity

It is currently believed that changes in the environment trigger changes in immune-related genes that lead to psoriasis. A phytochemical's multifaceted action on psoriasis is described in this section.

- *vera* (L.) Burm. Ghritakumari (Liliaceae)
- Tree of the *Betula alleghaniensis* species Britt. The yellow birch is a member of the Betulaceae family.
- *C. bonduc*(L.) Roxb. The feversnut/gray nicker bean belongs to the Caesalpiniaceae family
- A plant belonging to the *Eruca sativa*Rocket seeds (Brassicaceae)
- The Oregon grape is *Mahonia aquifolium*Rubisan(Berberidaceae)
- *Polypodium decumanum* Willd. (Polypodiaceae) Calaguala
- Linnaeus, *Rubia cordifolia*Madder (Rubiaceae)/Rubiace Radix
- *Saccharum officinarum* Linn. (Graminae) Sugarcane
- In the genus *Tabebuia avellanedae*Lor. ex.Red lapacho tree (Bignoniaceae)

Drug delivery system: Silver Nanoparticles

Several nanoparticles have gained considerable interest as a means of delivering drugs in a unique and advanced manner. The techniques used to provide specific therapeutic outcomes should be evaluated when distributing a pharmaceutical element to humans or animals. Several chemical units containing AgNPs were successfully combined to create a novel and effective drug delivery system that was capable of adapting to temperature and pH changes nanoscale-derived health care settings, highly contagious, and targeted at inflammation. [24]. In order to be effective, nanosystems for drug delivery must be simple to construct, easy to access, and highly reactive. A flexible drug concentration and discharging technology is also required to ensure effective drug delivery. In addition, its concentration should be lower than that of its main compounds, which should minimize its side effects [25]. As anticancer drugs can be carried by AgNPs either actively or passively, this area of research has attracted a lot of attention [26].

Silver nanoparticles for anti-psoriatic activity

Patient suffering, fatality, and substantial economic consequences may result from infections, which are serious therapeutic problems. It is difficult but necessary to control wound sprouting and clinical illness. Despite being the largest and most advanced organ in the body, the skin can be exposed to harmful environmental stimuli. When cutaneous wounds are created physically or chemically, they can severely impair skin function and even cause death, depending on the level of trauma [27, 28].

CONCLUSION

In the present study, we found that the plants showed bioactive properties that are beneficial to the treatment of psoriasis when used topically or as an adjuvant therapy. There are several notable anti-psoriatic properties associated





with silver nanoparticles, which are widely used in the medical industry to treat psoriasis. It is an economically, environmentally and economically efficient way of making nanoparticles using plant extracts, resulting in a more efficient work place, healthier communities, a less wasteful environment, and a safer product.

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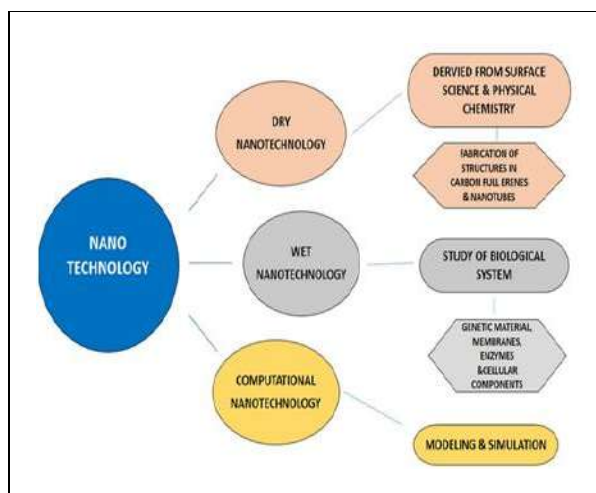


Figure.1: Disciplines of nanotechnology

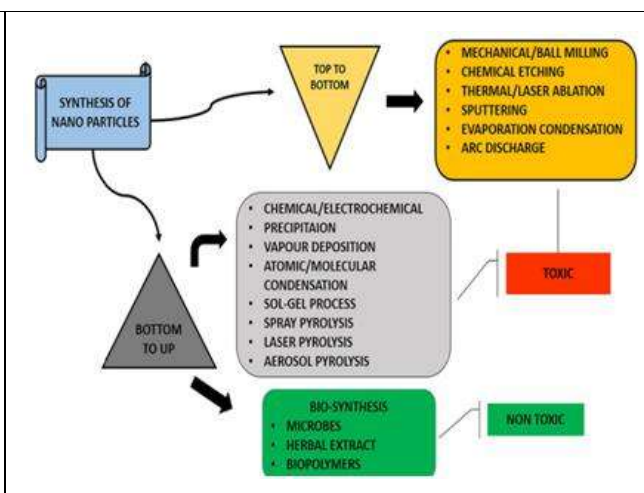


Figure.2: Different approaches for formulation of nanoparticles





Screening of Probiotic Isolates and its Bioactivity

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ABSTRACT

The study focuses on lactic acid bacteria, present in naturally fermented milk products in and near Davangere and have probiotic effects in the gastrointestinal tract. These products include curd made from cow, buffalo, sheep, goat milk and butter made from cow and buffalo milk. The task uses a natural fermentation technique with no artificial starting culture, as the lactic acid bacteria has native flora to ferment. Probiotic isolate is subjected to several activities to indicate potential probiotics. When the antibacterial activity was measured both before and after the pH was neutralized, it was found that *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhimurium*, and *Listeria monocytogenes* showed the greatest suppression of the food-borne pathogens. The probiotic isolates are exposed to varied pH values and salt concentrations at a predetermined incubation period. Some isolates tolerated low pH for up to eight hours, different concentrations of bile indicated lower bacterial growth as the bile concentration increased, and in the gastro intestine, the isolates naturally dropped vertically from the stomach to the intestinal state. All isolates reported positive β -galactosidase production and hydrophobicity of 78%. In our study, the isolates DGC-10 and DBB-9 demonstrated the highest probiotic potentials of all the isolates, indicating that the goat curd and buffalo butter samples have greater potential and can be commercially exploited as probiotic isolates for food products.

Keywords: antimicrobial activity, acid tolerance, hemolysis, lactic acid bacteria, naturally fermented milk.





INTRODUCTION

Probiotics, which are referred to as "living microorganisms," have been associated with positive health effects. Most of these bacteria benefit human health, performing several crucial physiologies. They aid in the digestion of food that our bodies can't break down on their own, they teach our immune systems to fight against invaders, they strengthen the lining of our intestines, and they may even affect the way we feel. In the digestive tract, probiotics work with our native microorganisms to generate compounds that benefit human health. Dietary supplements and various meals, particularly fermented dairy products like yoghurt and kefir, may include probiotics. To improve the acidity, texture, flavour, and aroma of food products and extend their shelf life, lactic acid bacteria (LAB) are frequently used [1]. Certain probiotic microorganisms, such as *Lactobacillus delbrueckii subsp. bulgaricus*, are known to provide a unique taste to food items due to their probiotic capabilities. The main sources of lactic acid bacteria are fermented food. This includes fermented vegetables, sour fruits and all dairy products. Although cow's milk is the kind of mammalian milk that is most often consumed globally, milk from other species, such as buffalo, sheep, goats, mares, camels, and yaks, may have had a greater historical and cultural impact in specific areas/countries [2]. One of the earliest fermented meals, naturally fermented milk products have been enjoyed by numerous ethnic tribes throughout the world since 6000 BCE [2]. The potential probiotic bacteria found in fermented milk products not only benefit the host's health but also offer substantial market worth in the food business [3]. Naturally fermented milk (NFM) products are popular throughout most of India [4], though their use varies considerably from area to region and community. Several dairy products, including milk, curd, and butter, have been cultured for lactic acid bacteria at Davangere. A popular fermented milk product from many ethnic backgrounds, curd is eaten across India. Butter is churning milk fat from curd into butter containing saturated fat, water, and milk proteins. This research aims to establish the potential role played by lactic acid bacteria isolated from fermented milk. The objective is to further help analyze comparative studies on various mammals, including cows, buffaloes, sheep, and goats. This work extends to identifying the most potential isolates based on various constraints.

MATERIALS AND METHODS

Collection of Sample

We collected 18 milk samples in and around the Davangere regions: Harihar, Honnali, Channagiri, Harapanahalli, Chitradurga, Hosadurga, Challakere, and Holalkere. We kept the cow, buffalo, sheep, and goat milk samples collected for fermentation naturally without adding any starter culture and made fermented milk products like curd and butter.

Characterization of LAB

The study used the pour plate method to characterize lactic acid bacteria from Davangere curd and butter from cow, buffalo, sheep, and goat milk samples. Samples were mixed with sterile saline, diluted to 10^{-1} to 10^{-8} , and plated on de Man Rogosa Sharpe agar (MRS) media. Mixed cultures were obtained and purified, and pure cultures were characterized by Gram staining.

Gram staining

Gram staining involves making a small colony smear on a glass slide and then smearing it with a crystal violet stain. The smear is washed with tap water, added Gram's Iodine, and soaked in 95% alcohol. The smear is then counterstained with safranin for a minute. The slide is then washed, drained, and air-dried before being examined under a microscope [5].

Catalase test

Bacteria identification using 3% hydrogen peroxide involves collecting a small organism from a well-isolated colony and placing it on a microscopic slide. Observing bubble formation. Positive reactions are indicated by effervescence, while catalase-negative responses are indicated by no bubble formation [6].





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Oxidase test

A sterile plastic inoculating loop removes new growth from the agar plate. A clean oxidase disc is moistened with water, and colony growth is rubbed. If cytochrome oxidase is present, the colour changes from colourless to indigo blue within 10-20 seconds. Negative results indicate oxidase [7].

Gas (co₂) production from glucose

Carbon dioxide production from glucose was checked to determine homofermentative or heterofermentative lactic acid bacteria isolates—Inoculate cultures in 5 mL MRS broth and incubated at 37°C for 24 to 48 hrs. The gas accumulation in the inverted Durham tubes indicated positive results, while no gas production indicated negative effects [8].

Ammonia from arginine

The arginine hydrolysis test was conducted using the [8] method in MRS broth, detecting ammonia using Nessler's reagent, indicating dark orange.

Fermentation of sugars

Inoculate cultures in tubes with 4 ml MRS broth containing phenol red and different sugars were incubated at 37°C for 48 hrs. Acid production was measured by colour change from red to yellow. Various sugars were used: lactose, maltose, glucose, fructose, cellobiose, mannose, rhamnose, melezitose, raffinose, ribose, xylose, sucrose, arabinose, trehalose, melibiose, salicin, and mannitol [8].

Growth in different NaCl concentrations

Salt tolerance of LAB isolates was tested by inoculating culture in MRS broth with 2%, 4%, 6%, 8%, and 10% of NaCl and incubating for 48 hrs at 37°C. Cultures were observed for growth after incubation [9].

Growth at different temperatures

Lactic acid bacteria growth was measured at 37°C, 42°C, 55°C, 60°C, and 65°C temperatures using the methods of [8,9]. Inoculated tubes with culture plates were incubated at 37°C, and growth was observed after 48-72 hrs.

Growth at different pH

The study measured lactic acid bacteria growth at different pH levels using the method of [8]. MRS broth was adjusted to 3.5, 4.5, 5.5, 7.2, 8.2, and 9.2 pH using 1 N HCl and 10% NaOH. The broth was filter sterilized, inoculated with 24 hrs old culture, and incubated at 37°C for 48-72 hrs.

Screening Activities**Determination of the antibacterial activity of lactic acid bacteria by the agar well diffusion method**

The study tested the antimicrobial activity of presumptive lactic acid bacteria isolates against enterotoxigenic: *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, and *Salmonella typhimurium*. These four pathogenic bacteria were previously isolated and identified (SDM Research Institute for Biomedical Sciences, Dharwad). Antimicrobial activity was evaluated by testing isolates on agar well diffusion plates. The indicator strain expanded on Mueller Hinton Agar, but the pathogen grew well on Brain Heart Infusion Agar. A 100 µl concentration of culture-free filtrate was used to fill the wells. The zone of inhibition was measured after incubating the plates at 37°C for 24 hrs [10].

Determination of antibacterial activity of lactic acid bacteria for the production of bacteriocin

Lactic acid bacteria can produce antibacterial compounds [11], and this study evaluated presumptive lactic acid bacteria isolates for their bacteriocin production. The LAB isolates were grown in MRS broth within a shaking incubator at 125 rpm at 37 °C for 48 hrs in anaerobic conditions (Remi- RS-24). The cultures were then collected into a centrifuge tube and centrifuged at 10000 g for 15 min at 4 °C (Remi-R8C) and were adjusted to pH 7.0 using 1M NaOH to exclude the antimicrobial effect of organic acid. The cell-free supernatant was filtered with a 0.2 µm

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membrane filter (Millipore) [12]. The antibacterial efficiency of the supernatant against foodborne pathogens was determined using the agar well diffusion method after the pH of the supernatant was neutralised. A 100 µL LAB culture-free filtrate was used to fill the wells. The zone of inhibition was measured after incubating the plates at 37°C for 24 hrs [10]. The LAB-producing zone of inhibition indicates the production of bacteriocin.

Determination of Acid tolerance

The [12] approach determined acid tolerance by placing various lactic acid bacteria isolates in MRS broth at several pH values (2 to 7). Growth was measured spectrophotometrically at 600nm for 4 to 48 hrs (Systronics-2202) and was tested after 16 hrs using a plating method.

Determination of Bile tolerance

We employed the procedure described in [13] to evaluate bile salt tolerance. We implanted lactic acid bacteria isolates into MRS broth containing 0.15%, 0.30%, and 0.45% bile salt to determine their tolerance to this compound. Incubate the culture broth for growth @37°C for 2 hrs. Growth in the broth was measured spectrophotometrically at 600nm and was tested using a plating method.

Determination of tolerance to stimulated Gastro-Intestinal conditions

A modified method was used to determine transit tolerance using simulated gastric juice [14]. Bacterial isolates were cultured overnight, suspended in 2ml of gastric juice. Spin at 200 rpm for 3 hours while incubating at 37°C. After inoculating the medium, centrifuge at 6000 rpm for 15 minutes, wash twice with phosphate buffer solution, and resuspend the pellet in intestinal fluid. The cells were incubated for three hours at 200 rpm at 37°C. Before and after the incubation period, total viable counts were conducted. The difference in colony counts was used to quantify the results.

Determination of antioxidant activity

The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay [15] was used to evaluate the antioxidant activity of several strains of lactic acid bacteria. In this experiment, we used the cell-free supernatant by adding 2 ml of DPPH to 2 ml of cell-free supernatant and letting the combination sit for 30 minutes in the dark. The samples were analysed using 517 nm absorbance. Standards were prepared using a DPPH solution in ethanol, while blanks were prepared using pure ethanol.

The percentage of DPPH scavenging activity was used to describe the antioxidant activity:

$$\text{DPPH scavenging activity (\%)} = \frac{\text{Absorbance of blank} - \text{Absorbance of sample}}{\text{Absorbance of blank}} \times 100$$

Determination of β-galactosidase assay

All bacteria were inoculated into tubes containing O-nitrophenyl-beta-D-galactopyranoside (ONPG), and the production of a yellow colour indicated positive β galactosidase activity [16]. The LAB strains were cultured at 37°C in a new MRS broth overnight. At 6000 rpm for 10 minutes, we centrifuged 1 ml of culture broth. 1 ml saline was added to the pellet, vortex, Centrifuge @ 6000rpm at 40°C for 10 minutes. To the pellet, add 1.5ml of Z-buffer, vortex; place the tubes in a 30°C water bath for 2 minutes; add 0.2ml of ONPG to each tube, vortex, and Return to the 30°C shaker (Note the time). The reaction was stopped when the yellow colour developed. The OD values were measured at 420nm, 550nm, and 650nm for each cell suspension.

$$\text{Activity} = \frac{\text{OD}_{420} - (1.75 \times \text{OD}_{550})}{\text{OD}_{650} \times t \times v} \times \frac{1 \text{ n mol}}{0.0045 \text{ ml cm}} \times 1.7 \text{ ml}$$

Determination of Cell surface hydrophobicity assay

In-vitro assessment of microbial adhesion to xylene was performed [17] to approximate the strain's capacity to attach to epithelial cells. Colonize MRS broth with the samples and keep them at 37°C overnight. 3ml cell suspensions Centrifuged @ 6000 rpm for 10 minutes, Pellets resuspended in 10ml saline, Add xylene Vortexed vigorously for 2 minutes. After phase separation, aqueous phase optical density was measured spectrophotometrically @ 560nm.



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$$\text{Percentage of Hydrophobicity (H \%)} = \frac{(A_0 - A_f)}{A_0} \times 100$$

A_f represents the optical density of the aqueous phase after adding xylene.

A_0 represents the optical density of the primary aqueous phase.

Determination of antibiotic sensitivity

The antibiotic sensitivity determination method involves inoculating presumptive lactic acid bacteria isolates onto plates and placing octodiscs. To grow the lactic acid bacteria we selected, we used 10 ml of fresh MRS broth and incubated it at 37°C for 48 hrs. To resuspend the pellets in saline, each isolate was centrifuged at 10000 rpm for 20 minutes. Agar plates are swabbed with a solution of pellets in saline and placed in an incubator at 37°C for 10 minutes. 24-hrs incubation at 37°C with antibiotic discs on the swabbed plates is recommended. Observe the zone of inhibition.

Hemolysis of blood Safety evaluation

Hemolytic activity was investigated [18]. The fresh cultures were streaked on the surface of the Sheep Blood Agar Plate; the plates were incubated at 37°C for 24 to 48 hrs. The plates were tested for hemolysis after incubation.

Molecular Identification

DNA Extraction

Based on probiotic attributes, the two isolates that showed the dominant character of LAB were selected from 12 LAB strains. The total genomic DNA of two representative strains of LAB was extracted from 2 ml samples of overnight cultures grown in MRS broth at 30°C according to the methods of [19].

16S rRNA Gene Sequencing

The 16S rRNA gene was amplified using PCR mixtures (25 µL) that contained 30–50 ng of template DNA, 1 µM of forward primer 27F, and 1 µM of reverse primer 1492R [20]. The amplification process was carried out using a PCR Master Mix (Promega) and a SimpliAmp™ Thermal Cycler (Thermo Fisher Scientific) according to standard protocol. The purity of the PCR amplicons was assessed using 1% agarose gel electrophoresis with 10 mg/mL of ethidium bromide present. The results were then examined using the Gel Doc System (Ultra-Violet Products Ltd.). The resulting sequencing files are in AB1 format, which may be seen with programmes like FinchTV. DNA datasets were compared using the BLAST (Basic Local Alignment Search Tool) programme to look for sequence similarities found in the NCBI database. The phylogenetic analysis using Molecular Evolutionary Genetics Analysis software (MEGA 11).

RESULTS

Davangere curd, buffalo butter, sheep butter, and goat butter were all found to have lactic acid bacteria (LAB).

Curd, made from cow, buffalo, sheep, and goat milk, and butter, made from cow and buffalo milk, were naturally fermented sources of lactic acid bacteria (LAB) in Davangere regions (Figure- 1). Sixty isolates were analysed for morphology; 43 were suspected to be LAB based on Gram's response, microscopic inspection, and catalase and oxidase assays. The isolates from the samples in the study were designated as DCC for cow curd, DBC for buffalo curd, DSC for sheep curd, DGC for goat curd, DCB for cow butter, and DBB for buffalo butter. Ten isolates were obtained from (DCC), consisting of (7 rods and 3 cocci). Ten isolates from (DBC) consisting of (3 rods, 6 cocci, and 1 yeast), ten isolates from (DCB) consisting of (7 rod, 3 cocci), ten isolates from (DBB) consisting of (6 rods, 4 cocci), ten isolates from (DSC) consisting of (4 rods, 5 cocci, 1 yeast), and ten from (DGC) consisting of (5 rods, 5 cocci) cultures. Microscopic examination of the isolates showed the predominance of gram-positive rods (54%) and cocci (43%), followed by yeast species (3%). The strains DCC-1, DCC-9, DBC-2, DBC-10, DCB-5, DCB-9, DBB-2, DBB-9, DSC-3, DSC-8, DGC-4, and DGC-10 were chosen for further study because they are gram-positive, non-motile, rod-shaped bacteria that are also catalase-negative and oxidase-negative.





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Characterization of lactic acid bacteria (LAB) by phenotypic and biochemistry in Davangere dairy products: cow, buffalo, sheep, goat curd, and cow and buffalo butter.

The phenotypic characterisation of LAB in terms of individual samples is shown in (Tables 1) and (Figures 2, 3, and 4). From twelve isolates, three isolates produced CO₂; ten isolates showed the presence of ammonia. Several different types of sugars were tested, and it was shown that LAB isolates could ferment arabinose, dextrose, fructose, lactose, mannose, sucrose, and xylose. Twelve distinct isolates were tested at several conditions, including 37°C, 42°C, 55°C, 60°C, and 65°C temperatures, pH levels of 3.5, 4.5, 5.5, 7.2, 8.2, and 9.2, and salt concentrations of 2%, 4%, 6%, 8%, and 10%. The isolates that showed dominant growth at different salt concentrations are DGC-10 in (6%), DCC-1 in both (2% & 4%), DBB-9 in both (8% & 10%) and there is no growth in any isolate except DBB-9 in (10%). In different pH level the highest growth isolates are DBB-9 at pH-4.5, 5.5, & 9.2, DCC-9 at pH-7.2, DSC-3 at 3.5 and DBB-2 at pH-8.2. In different temperature highest growth taken by isolates are DBB-9 at 37°C, 60°C & 65°C, DGC-10 at 42°C & 60°C, and 65°C and DSC-8 at 55°C.

Screening of Presumptive LAB Isolates For Probiotic Attributes**Antimicrobial activity of the chosen LAB was tested using the agar well diffusion method**

The capacity to create antimicrobial compounds against pathogens aids in immune system regulation [19, 20], which is why lactic acid bacteria are so popular as probiotic strains [20]. Twelve different cultures were tested for their potential to prevent the growth of four types of food-borne pathogens: *Listeria monocytogenes*, *Salmonella typhimurium*, *Escherichia coli*, and *Staphylococcus aureus*. The LAB isolates' antibacterial activity results are shown in (Figure 5). The highest observed growth inhibition zone measured in this study was 20mm by DCB-9, DBB-9 against *S. aureus*, *S. typhimurium*, and *L.monocytogenes*. Seven isolates, DCC-9, DBC-2, DCB-5, DBB-9, DSC-3, DSC-8, and DGC-10, showed inhibition against all four foodborne pathogens. One isolate, DSC-8, did not show any inhibition against *E.coli*, while DBC-10 and DBB-two did not show inhibition against *S. aureus*. The isolates DCC-1 and DCB-9 did not show inhibition against *L.monocytogenes*. All the isolates had inhibitory activity against *S. typhimurium*. Previous research looked at how effective LAB strains were as antibiotics, and the results suggested they may be useful as probiotics.

Determination of the antimicrobial activity of lactic acid bacteria isolates for the production of bacteriocin

Antimicrobial substances such as organic acids, hydrogen peroxide, diacetyl, inhibitory enzymes, and bacteriocin may contribute to the efficacy of the strains tested to suppress infections [21]. Many chemicals with antibacterial activity may be produced by LAB, which is widely recognised. The current investigation assessed the potential to produce bacteriocins by the putative LAB isolates. This was achieved by adjusting the pH of the supernatant. Results shown in (Figure-6) show that only two isolates, DCC-9 and DBB-9, showed inhibition against all four tested pathogens. Four isolates (DBB-2, DSC-3, DSC-8, and DGC-10) showed inhibition against three pathogens, i.e., *S.aureus*, *S.typhimurium*, *L.monocytogenes* and did not establish any inhibition zone against *E.coli*. DCC-1 and DCB-9 showed antimicrobial activity against only *S.aureus* and *S.typhimurium*. Antimicrobial activity was detected against *Escherichia coli* and *Staphylococcus aureus* in isolates DBC-2 and DCB-5. Against infections, DGC-4 does not show much antibacterial action, indicating it does not create bacteriocin. Studies on *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, and *Salmonella typhimurium* suggest that LAB in the NFM products may impact the lower survival of hazardous bacteria. The potential causes of the antibacterial activity of the cultures recovered from the various materials include their capacity to create one or more chemicals. Our study tested the antimicrobial activity before and after neutralizing the pH. In these reports, seven isolates (DCC-9, DBC-2, DCB-5, DBB-9, DSC-3, DSC-8, and DGC-10) showed antimicrobial activity against all the pathogens tested before neutralizing the pH of the supernatant. After neutralizing the pH of the supernatant, only two isolates (DCC-9 and DBB-9) had antimicrobial properties against all four foodborne pathogens. So, these isolates are considered to produce a very strong bacteriocin against the tested pathogens.

Studies on acid tolerance of the selected LAB isolates

To guarantee the survival and development of putative probiotics in the gastrointestinal tract, standard in vitro studies are required for their characterization. The rate of survival of the isolates was evaluated at various pH levels.



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One of the most crucial features of a putative probiotic strain is its capacity to thrive at an acidic pH [22], an in vitro mimic of the human stomach [23]. The findings are shown in (Figure-7a-7l). Isolate growth rates were measured at 4h, 8h, 12h, 24h, and 48h intervals. There was no transition at pH 2 and 3, but most isolates exhibited optimal growth at pH 6 and 7, declining growth at pH 4 and 5. The twelve LAB isolates from different sources were assayed for acid tolerance. The highest tolerance was shown by four isolates, namely DBC-10, DCB-9, DBB-9, and DGC-10, which could withstand pH 2 - 7. The isolate showed optimal growth between pH 5 - 7 up to 12 hours of incubation. Isolates DCC-1, DCC-9, DBC-10, and DGC-4 No change was observed after 12 hours in pH-2-4. The seven isolates, DCC-1, DCC-9, DBC-10, DCB-5, DCB-9, DBB-9, and DGC-10, could withstand pH- 7 for up to 48 hrs. Isolates DBC-2, DBB-2, and DSC-8 were not able to survive highly acidic conditions and were not able to grow. These results indicate that the isolates (DBC-10, DCB-9, DBB-9, DGC-4, and DGC-10) could tolerate and survive low pH for up to 8 hours of incubation. Previous research has shown that LAB strains vary in their tolerance levels [24]. To investigate how different pH levels affected bacteria, the number of viable bacteria was counted using the plate count method. The viability of the isolates was evaluated after 16 hrs of incubation at different pHs, as shown in (Figure-8). All the isolates, Except for three isolates, DBC-2, DBB-2, and DGC-4, could tolerate and survive at higher pH. Results indicate that those strains unable to accept a pH of 2 could handle a higher pH.

Studies on bile tolerance of the selected LAB isolates

Probiotic bacteria candidates' ability to tolerate intestinal bile salt is important for their selection and survival in the GIT [25]. Research on the viability of LAB isolates in the presence of varying quantities of bile revealed that bacterial growth slowed with increasing bile concentrations. The effect of different bile concentrations is shown in (Figure 9). Isolate growth rates were measured at 2 hours. The results were similar for all the lactic isolates tested. The change was maximum in the experimental control, where bile was not supplemented. The cell viability of isolates varied at different bile concentrations (Figure 10). At 0.15% bile salt supplementation, isolate DCC-1 showed higher viability. At a bile concentration of 0.30% and 0.45%, the strain DBB-9 showed high viability, and only isolate DBC- 2 showed the lowest at all concentrations of bile than other isolates. In the present study, 0.3% and 0.45% bile concentrations showed higher viability in the isolate DCC-1 upto 2 hours. Previous studies [26] determined that the typical bile concentration is 0.3%, while the normal bile concentration for an individual is between 0.3% and 0.5%. The lipid bilayer and integral protein of bacterial cell membranes are hypothesised to be compromised by bile acids, disrupting cell homeostasis, releasing cytoplasmic material, and ultimately leading to cell death. Probiotic isolates that can thrive in high bile concentrations are much sought after.

Effect of gastrointestinal conditions on selected lactic acid bacteria

As probiotics, lactic acid bacteria should be able to thrive in the digestive system. Food takes around four hours to move through the small intestine. Recent publications [24] show that LABs had a greater survival rate in simulated stomach acid and intestinal juice than previously thought. Our LAB isolates showed survival rates of up to 99.69% and 84.94%, respectively. The twelve isolates were screened for their survival under simulated gastrointestinal conditions. Five isolates (DBC-10, DCB-9, DBB-2, and DSC-8) did not survive these conditions. Only six probiotic isolates survived the simulated gastrointestinal disorders. Different LAB isolates' susceptibilities to stomach and intestinal juice are shown in (Figure-11). Isolate DBB-9 showed the highest survival level, with 10.5% of cells surviving stimulated gastric conditions, and DCB-5 showed the lowest survival isolate, with 0.36% of cells surviving enabled gastric disorders. The highest decline in the viable counts of the isolates from simulated gastric conditions to intestinal conditions was in DCB-5. It was observed that the viability of the isolates diminished vertically from gastric ambience to the intestinal environment. Six probiotic isolates from the current study persisted under simulated gastrointestinal conditions. Isolates DCC-1, DCC-9, DBB-9, DSC-3, DGC-4, and DGC-10 showed the greatest increase in viability from stomach to intestinal conditions, suggesting they may have useful effects as probiotics.

Antioxidant activity

Free radical scavenging experiments were used to test the twelve isolates for antioxidant activity. Historically, the antioxidant properties of natural compounds were measured using the DPPH radicals. The ability of a food or organism to scavenge and destroy free radicals is known as its antioxidant capability. The ability to scavenge DPPH





radicals is a good indicator of antioxidant activity. Among the twelve selected isolates, the potent scavenging activity was shown by the DBB-9 isolate, which was up to 69%. The antioxidant activity of all the LAB isolates was >39%, apart from that of isolate DCB-5 (2.5%) and DCC-9 (2.9%). The result is shown in (Figure-12). 53.78% of DPPH free radicals were scavenged at the greatest level in the prior investigation [27].

β-galactosidase assay

Hydrolysis of the glucosidic lactose link is an important step in carbohydrate metabolism, and β-galactosidase plays a key role in this process [28]. It has been found that some of the strains recovered from fermented milk products had high levels of β-galactosidase activity. The production of β-galactosidase was confirmed in every single isolate. Isolate β-galactosidase activities ranged from 4.22 to 93.3%. The enzyme activity of β-galactosidase was most abundant in the isolates DGC-10 and DBB-9. (Figure-13) shows the outcomes of the test. β-galactosidase activity was also found in a prior investigation using isolates from NFM products [29]. In the present study, except for one isolate, all other isolates had positive results for β-galactosidase production. The isolate DGC-10 shows up to 93% of activity.

Cell surface hydrophobicity assay

A probiotic's capacity to adhere to intestinal cells is a crucial selection factor [30]. Probiotic strains' strong bond to xylene. Hydrophobicity ranged from 76.6 per cent to 3.34 per cent across all examined strains. Hydrophobic strains were defined as those having a hydrophobicity of 40% or above [31]. The hydrophobicity of isolate DGC-10 showed greater adhesion potentials determined by the MATH assay. The strain DGC-10 showed 77.6% affinity towards xylene. DBC-2, DBB-9, and DGC-10 showed above 40% affinity towards xylene. Only one isolate, DCC-1, showed the least association. The results are shown in (Figure 14) DGC-10, DBB-9, and DBC-2 were the most hydrophobic of the LAB strains tested in our research, with as important as high as 78%. In a previous study, the isolates from fermented foods had good hydrophobicity and showed 80% of hydrophobicity [29].

Determination of antibiotic sensitivity of LAB isolates

Since lactic acid bacteria (LAB) were deemed GRAS by the FDA, they have been widely employed in producing and consuming fermented foods without any reported health risks (USFDA). Food safety and public health concerns have been raised due to antibiotic resistance in LAB isolated from food [32]. The antibiotic susceptibilities of the LAB isolates were determined using a disc diffusion method. The following antibiotics were used: Ca = Ceftazidime, Cf = Ciprofloxacin, Ce = Cephalexime, Na = Nalidixic acid, Nf = Nitrofurantoin, Nx = Norfloxacin, Nt = Netillin, Of = Ofloxacin. The isolates differed in their sensitivity toward the antibiotics. The zone of inhibition (ZOI) in millimetres indicates the antibiotic sensitivity of the isolates (Figure-15). The highest growth inhibition was observed for DGC-4 against Cf and DGC-10 against Ce. All twelve isolates were susceptible to Cf, while Ca and Na were highly resistant to all isolates except for DCC-1, DBB-2, & DGC-10, which showed sensitivity against Ca. Only isolate DBB-2 showed sensitivity against Cf and further was resistant to all seven other antibiotics. The isolates DBC-2, DCB-5, DBB-2, and DSC-8 resisted Nx.

Hemolytic activity

The FAO/WHO guidelines for evaluating probiotics recommend safety. All the selected isolates showed no positive hemolysis activity so that they could be regarded as safe concerning non-hemolytic activity. In addition, probiotic candidates were not supposed to cause hemolysis in people or animals after ingestion. This led us to test the 12 LAB isolates for their hemolytic capabilities. None of them were hemolytic, consistent with prior research [24].

Molecular Identification

Total genomic DNA of 2 representative strains of LAB was extracted and amplified (Figure-16a – 16b) and identified by partial 16S rRNA, which gene sequencing compared with the NCBI database for their phylogenetic relationship using the software MEGA 11 (Figure-17). Based on molecular identification, the following species of LAB were identified from butter and curd of the Davangere district with percentage similarity of LAB, DBB-9 *Lactiplantibacillus plantarum* (96.64%), and DGC-10 *Lactobacillus fermentum* (98.46%) (Table



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2). *Lactiplantibacillus plantarum* and *Lactobacillus fermentum* were reported from many fermented milk products from different countries [35]

CONCLUSION

This study looks into the probiotic capabilities of lactic acid bacteria isolated from fermented milk products made in the Davangere areas. Based on the difference in morphology, sixty colonies were isolated, of which forty-three were presumed to be LAB. Twelve LAB isolates were tested for phenotypic characterization and probiotic attributes. Of the twelve isolates, three produced CO₂; ten isolates showed the presence of ammonia, and it was found that LAB isolates fermented the sugars. The isolates DGC-10 & DBB-9 demonstrated good growth in salt concentration, pH, and temperature in their characterisation. All twelve LAB isolates tested positive for antimicrobial activity, with the best inhibition against *E. coli*, *S. aureus*, *S. typhimurium*, and *L. monocytogenes*. These LAB isolates were selected for further tests such as acid tolerance, bile tolerance, tolerance to gastrointestinal stimulation conditions, antioxidant activity, β -galactosidase assay, hydrophobicity, and sensitivity testing. In bile activity, DCC-1 & DBB-9 show both high and low viability at different concentrations, and the results for the gastrointestinal action the best was the DGC-10 isolate delivering 80% survival. These received additional testing for antioxidant efficacy. DBB-9, an isolate, demonstrated the highest activity, resulting in 70% of activity. Increased production of β -galactosidase enzyme activity was observed in the isolate DGC-10. The hydrophobicity of isolate DGC-10 showed greater adhesion potentials determined by the MATH assay. All twelve isolates were susceptible to Cf, while Ca and Na were highly resistant to all isolates except isolates DCC-1, DBB-9 & DGC-10. Therefore, DCC-1, DBB-9 & DGC-10 show the best probiotic attributes among all the isolates. In these, goat curd and buffalo butter samples show more potential. Themolecular identification was carried out by two isolates, DBB-9 & DGC-10. Both showed more potential compared with other isolates. The lactic acid bacteria that have been identified for DBB-9 are *Lactiplantibacillus plantarum* (Accession No.: CP028226) and DGC-10 *Lactobacillus fermentum* (Accession No.: KR604711), respectively. Future research for these isolates is promising and has economic potential as a probiotic food ingredient. The research confirmed that the bacteria obtained from naturally fermented milk were lactic acid bacteria with probiotic properties and have beneficial health effects. To validate their effectiveness in promoting human health, more research is needed.

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Table.1: Biochemical characteristics and fermentation ability of representative LAB strains isolated from Fermented milk samples of Davangere.

Isolates	Gas production	Arginine test	Sugar Fermentation						
			Arabinose	Dextrose	Fuctose	Lactose	Mannose	Sucrose	Xylose
DCC-1	+	+	-	+	-	+	-	-	+
DCC-9	+	+	-	+	+	+	-	-	-
DBC-2	-	+	L+	+	+	+	L+	-	-
DBC-10	-	+	-	+	+	-	+	+	+
DCB-5	-	-	+	+	+	+	+	+	-
DCB-9	-	+	+	+	+	+	-	+	-
DBB-2	-	+	+	+	+	+	+	+	+
DBB-9	-	+	+	+	+	+	+	-	+
DSC-3	-	+	+	+	L+	L+	-	-	-
DSC-8	-	+	+	++	L+	+	-	L+	-
DGC-4	+	-	+	+	+	L+	-	+	L+
DGC-10	-	+	-	L+	L+	-	L+	-	L+

Growth (+), No growth (-), Less growth (L+)

Table.2: Molecular identification of bacterial strains isolated from naturally fermented milk products of Davangere by 16S rRNA gene sequence based on Basic Local Alignment Search Tool (BLAST)

Isolate Code	E value	Similarity (%)	Query coverage	Top-hit taxon (EzTaxon)	Top-hit strain type	Accession Number
DBB-9	0.0	96.64%	99%	<i>Lactiplantibacillus plantarum</i>	SRCM101187	CP028226.1
DGC-10	0.0	98.46%	99%	<i>Lactobacillus fermentum</i>	VP2	KR604711.1



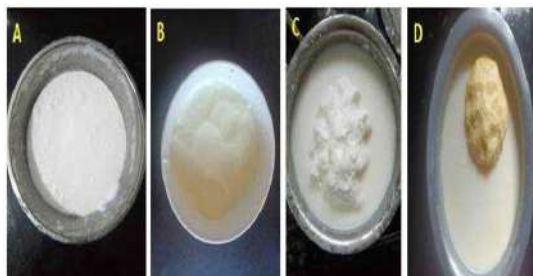


Figure.1: Fermented milk product samples of Davangere regions (a) buffalo curd, (b) cow curd, (c) buffalo butter and (d) cow butter.

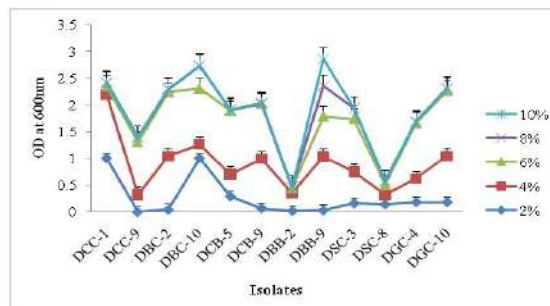


Figure.2: Phenotypic characteristics at different salt concentration to LAB strains isolated from Fermented milk samples of Davangere.

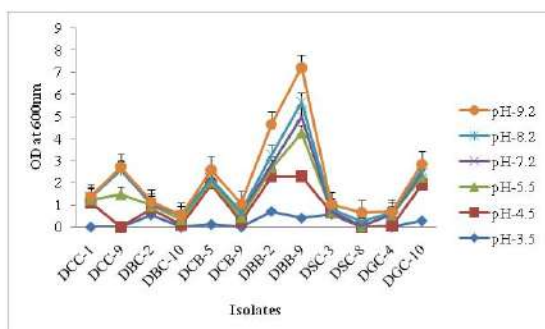


Figure.3: Phenotypic characteristics at different pH levels to LAB strains isolated from Fermented milk samples of Davangere.

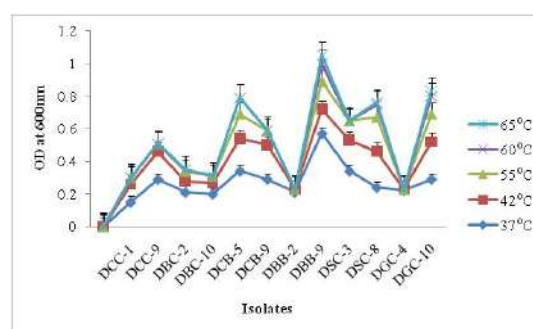


Figure.4: Phenotypic characteristics at different temperatures to LAB strains isolated from Fermented milk samples of Davangere.

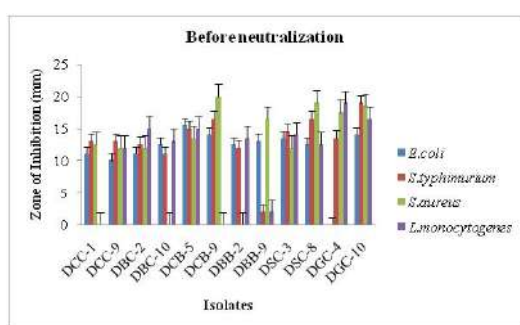


Figure.5: Antimicrobial activity by different selected LAB isolates against four food-borne pathogens without neutralising the pH. [pH values of isolates, DCC-1=4.3, DCC-9=4.6, DBC-2=4.5, DBC-10=4.2, DCB-5=6.1, DCB-9=5.9, DBB-2=6, DBB-9=6.2, DSC-3=5.1, DSC-8=4.9, DGC-4=5.7, DGC-10=5.2]

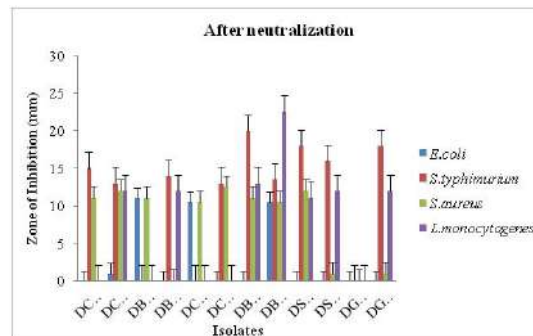
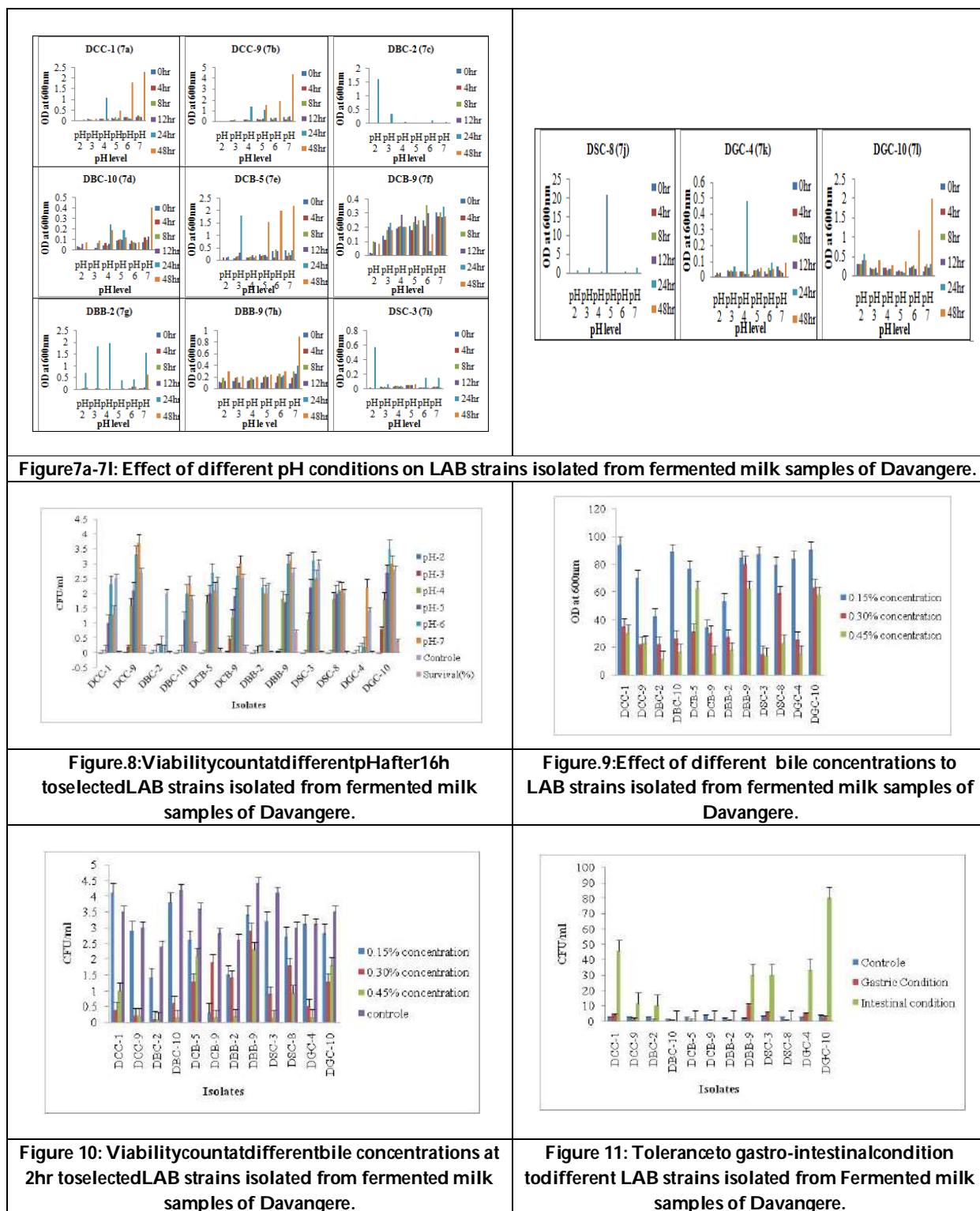


Figure.6: Antimicrobial activity of selected LAB isolates against four food-borne pathogens after neutralising the pH. [The pH value is neutralized to pH7 to all isolates]







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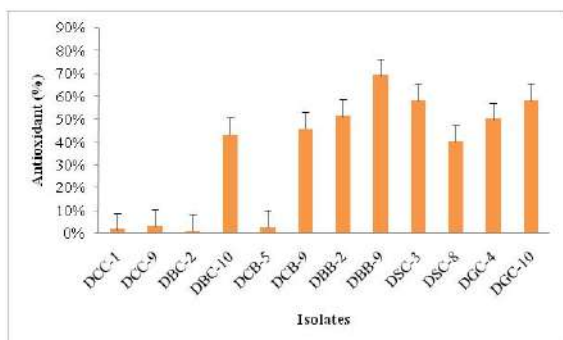


Figure.12: Antioxidant activity by DPPH to LAB strains isolated from fermented milk samples of Davangere.

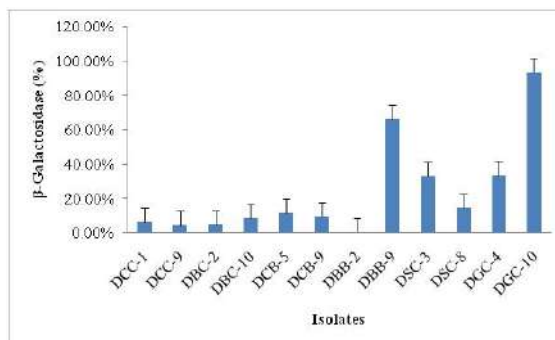


Figure.13: β-galactosidase activity by ONPG assay to LAB strains isolated from fermented milk samples of Davangere.

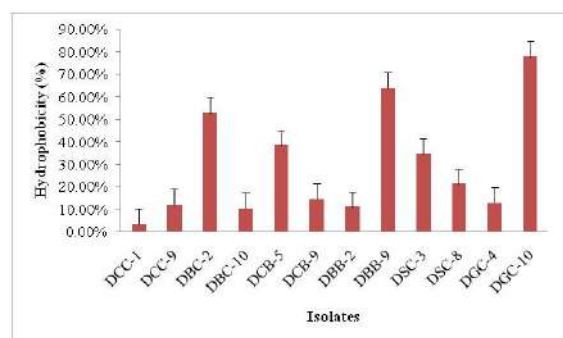


Figure.14: Hydrophobicity assay using xylene to LAB strains isolated from fermented milk samples of Davangere.

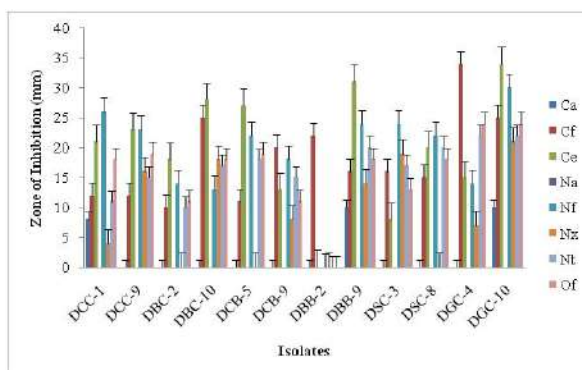
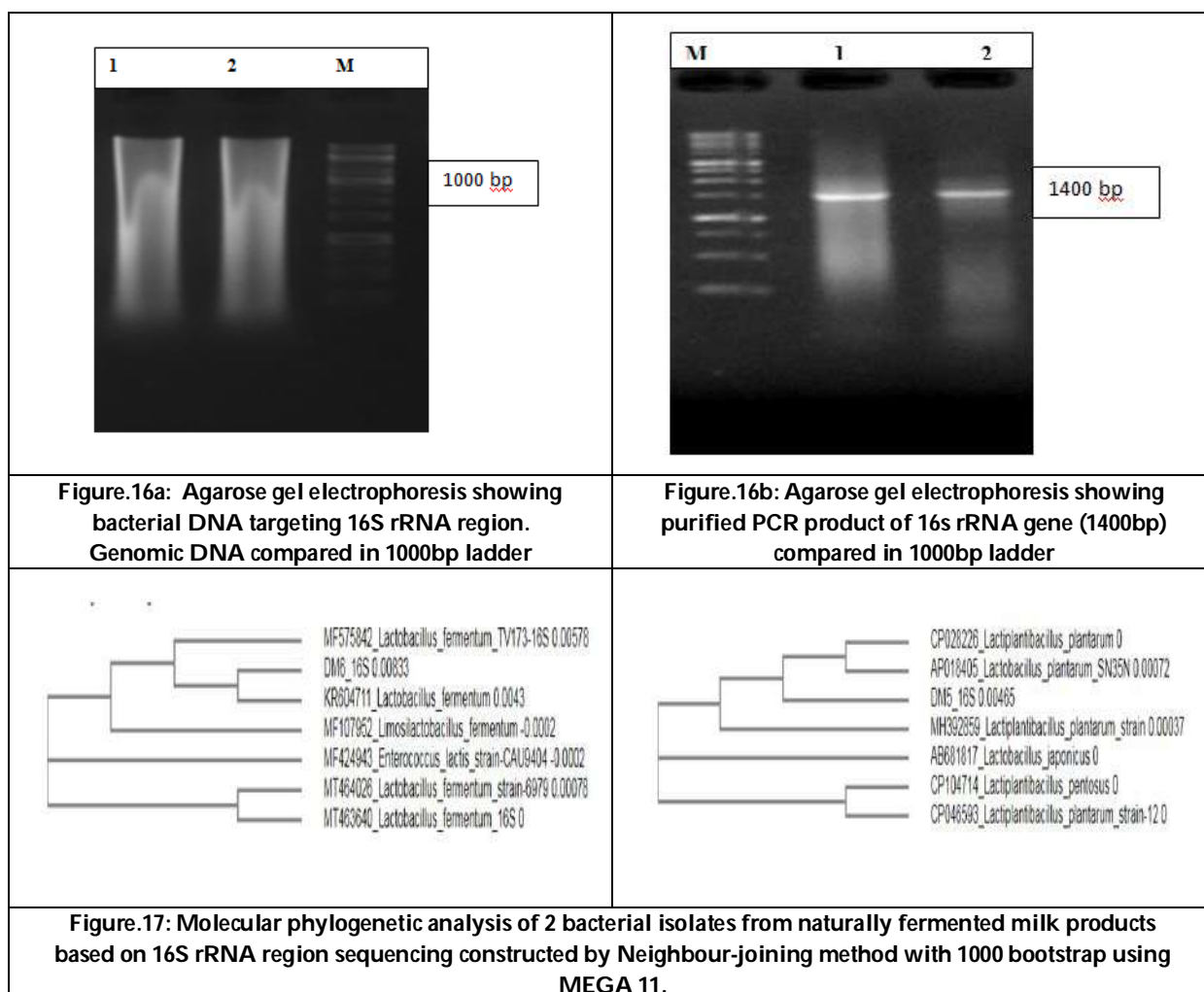


Figure.15: Antibiotic susceptibility against eight antibiotics on LAB strains isolated from fermented milk samples of Davangere. [Antibiotics used, Ca = Ceftazidime, Cf = Ciprofloxacin, Ce = Cephalexin, Na = Nalidixic acid, Nf = Nitrofurantoin, Nx = Norfloxacin, Nt = Netillin, Of = Ofloxacin]





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Advancements in Machine Learning for Wildlife Conserv A Comprehensive Survey

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ABSTRACT

This paper explores the use of machine learning (ML) and artificial intelligence (AI) in wildlife conservation. With traditional methods being limited by time and resources, AI and ML offer innovative solutions for monitoring endangered species and their habitats. These technologies are applied in various areas, including wildlife population monitoring using camera traps, drones, and satellites. Machine learning also plays a crucial role in detecting poaching activities, analyzing animal behavior, and improving species re-identification methods. The paper highlights how AI models are transforming conservation efforts by automating tasks, extracting insights from large datasets, and predicting trends. The authors also emphasize the potential for future research in refining these technologies to further enhance wildlife conservation strategies, improve model accuracy, and incorporate new sensor technologies for better-informed decision-making in protecting biodiversity.

Keywords: Wildlife conservation · Machine learning · Artificial intelligence · Species monitoring · Poaching detection





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INTRODUCTION

Nowadays, wildlife conservation is crucial because many species are at risk of disappearing forever due to human activities like habitat destruction and pollution. Wildlife conservation means protecting animals and their habitats from harm. It's important to act now to preserve wildlife for future generations to enjoy and to ensure the planet remains healthy and diverse. Wildlife conservation is changing a lot because of new technology called artificial intelligence (AI) and machine learning (ML). These powerful tools offer unprecedented capabilities to monitor, protect, and manage endangered species and their habitats. Traditional approaches to wildlife conservation have relied on manual data collection and analysis, often limited by time, resources, and accessibility. AI and ML are revolutionizing this process by automating tasks, extracting insights from vast amounts of data, and predicting future trends. Here are some of the key ways AI and ML are being used in wildlife conservation

Monitoring Wildlife Populations

The authors in [36], [40] propose AI/ML based algorithms that can analyze images from camera traps, drones, and satellites to identify and count individual animals, even in dense vegetation or vast landscapes and also can analyze audio recordings to identify different animal species based on their unique vocalizations. Different AI based algorithms can be used to identify individual animals based on unique physical features, such as their facial patterns or stripes.

Combating Poaching and Illegal Wildlife Trade

Artificial Intelligence (AI) plays a crucial role in advancing wildlife conservation efforts through predictive analytics, real-time detection, and habitat management. By analyzing historical data, AI models [42] can predict poaching hotspots and identify high-risk areas. This enables rangers to focus their patrols more effectively, reducing illegal activities and safeguarding vulnerable species. Moreover, AI algorithms can process live camera feeds to detect suspicious activities, such as poaching or illegal logging. These real-time insights allow for immediate intervention and the arrest of offenders, enhancing the efficiency of law enforcement in protected areas. AI also extends its capabilities to social media monitoring [11]. By analyzing online conversations, it can identify individuals or networks involved in the illegal trade of wildlife. This information helps disrupt these networks and prevent future trafficking, providing a proactive approach to combating wildlife crime. In terms of habitat management and conservation, AI has been shown to be instrumental [42] in monitoring changes in land use. By analyzing satellite imagery, AI can detect deforestation or habitat fragmentation and identify areas that require restoration. Conservationists can use this information to prioritize efforts and mitigate the adverse effects of human activities on wildlife habitats. Collectively, these applications of AI contribute to more effective and informed conservation strategies, ensuring the protection of biodiversity for future generations.

Literature Survey

Research work [37] explores the integration of machine learning (ML) in wildlife conservation, highlighting its growing impact on addressing critical challenges. Their study highlights notable applications such as species detection through image analysis, remote sensing to track animal movements, and predictive modeling for poaching, with deep learning algorithms driving improvements in accuracy and efficiency when handling large-scale ecological datasets. The authors in [31] highlight the importance of combining machine learning (ML) with domain-specific expertise to address challenges in wildlife conservation. Despite issues such as data biases, clarity, and ethical concerns, their study emphasizes the transformative potential of machine learning to advance monitoring, management, and preservation initiatives. For example, Carolina wren vocalizations were detected across more than 35,000 hours of passive acoustic monitoring data from Ithaca, New York. This approach enabled researchers to document the gradual recovery of the wren population after a harsh winter in 2015 [40]. Machine learning algorithms have also been employed to analyze the movements of savannah herbivores equipped with bio-logging devices. These algorithms help identify human threats and localize



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intruders within a range of 500 meters. Another study [35] introduces TRex, an image-based tracking software capable of monitoring the movement and posture of hundreds of individually recognized animals in real-time. Additionally, pose estimation tools such as DeepPoseKit and DeepLabCut have been developed to track the body positions of individual animals from video footage, including drone imagery. These tools also allow researchers to estimate 3D postures of animals in their natural habitats [35]. Figure 1 shows the examples of the research that use machine learning based systems in animal ecology. The use of various sensors has become common in animal ecology research. Many studies integrate data collected from multiple sensors at the same geographic site or across different locations to gain a more comprehensive understanding of ecological processes. For example, the Sentinel-2 satellite, developed by the European Space Agency (ESA), has been widely utilized, with image data often provided by the U.S. Geological Survey [35]. Table 1 depicts the details of the sensors used in the conservation of digital wildlife. Column I shows the name of various sensors. Column II shows the specific location of their use. Column III shows the type and Column IV shows the task performed by the sensors. Lastly, Column V shows the count of the sensors used. The sensors include iNaturalist, SAVMAP, Zooniverse, and iRecord, each contributing to different aspects of wildlife conservation efforts. Addo Elephant National Park in South Africa was selected as the study site for its diverse and dynamic environment, as well as its high elephant population [26]. The park spans 1,640 square kilometers, making it the third-largest national park in the country. For this study, elephants were observed primarily in the Main Camp area, particularly near the Hapoor Dam. The park provides a spectrally complex background due to its mix of open savannah and woodland. Elephants frequently move between these habitats and often seek shade under trees during the afternoon. Additionally, they exhibit unique behaviors such as covering themselves in mud to cool down and adopting various postures while foraging, playing, or sleeping. These behaviors, combined with their movement across diverse landscapes, result in constant variations in their appearance and shape. The park experiences year-round rainfall and has four distinct seasonal periods: early wet (October–December), late wet (January–March), early dry (April–June), and late dry (July–September) [1]. To build a comprehensive dataset, training and test images of elephants were collected across multiple seasons and years [10]. This strategy ensures the dataset captures the wide range of elephant behaviors, appearances, and environmental conditions. Table 2 provides a list of satellite images used to train and test a model to detect elephants. Here, Column I and II show the date of acquisition of the satellite images and name of the satellite used for capturing respectively.

Columns III, IV and V show the count of the images of elephants for training, validating and testing of machine learning models respectively. The data spans from 2014 to 2019, with varying numbers of labeled elephants across different images. Figure 2 shows an example of the satellite image of Addo Elephant Park at South Africa. Since the early 1990s, camera trapping has emerged as an important tool in wildlife conservation and research, enabling the study and monitoring of animal behavior and ecology [33]. The use of trail cameras has gained popularity due to their ability to meet the growing demands and specializations in wildlife management. Despite their advantages, traditional methods for analyzing camera trap data, such as manually classifying and reviewing images and videos—pose significant challenges. Without software assistance, this manual process can be time-consuming and labor-intensive, leading to a reduction in sampling intensity and potentially limiting the scope of research [2]. However, camera traps offer several key benefits in the field of wildlife research. They can be used for a wide range of applications, including studying species distribution, tracking disease transmission and vaccination efforts, estimating populations, monitoring nest predation, analyzing animal activity patterns, and assessing wildlife crossings and diet. Camera trapping is less invasive than many other methods, allows for consistent and simultaneous observation, and can be especially useful in studying elusive or aggressive species in dangerous or remote areas. Furthermore, this method provides photographic and video evidence, reduces observer bias, and is cost-effective. These features make camera trapping an indispensable tool in modern wildlife conservation efforts. Camera trapping has proven to be an efficient and effective method for remotely monitoring animal populations and obtaining real-time observations [3]. Historically, wildlife monitoring relied on traditional techniques such as visual or auditory surveys, track counts, scat analysis, detection dogs, driven counts, and physical trapping. While valuable, these methods often posed challenges in terms of accessibility, intrusiveness, and reliability. Camera traps, in contrast, offer unique advantages, particularly for



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monitoring wildlife in remote or hard-to-access areas. For example, they have been successfully employed to observe Florida Key deer on outer islands that were difficult for researchers to visit. In addition, camera traps are especially useful in scenarios where human presence might disturb wildlife, extended monitoring periods are required, or observations must be made in dangerous or isolated environments. The versatility of camera traps extends to situations where permanent verifiable data is needed or when their capabilities, such as night vision and motion detection, surpass those of the human eye. These advantages make camera trapping an indispensable tool for modern wildlife research and conservation efforts. The use of camera traps is based on the mark-recapture technique by using Petersen estimators. Camera traps have proven valuable in monitoring vaccine uptake by tracking the frequency of visits to bait sites and observing individual bait consumption [33]. Furthermore, these devices facilitate the study of disease transmission, both within and between species, by capturing behaviors such as direct contact (like, nuzzling) and indirect interactions (like, fecal-oral contact or shared site usage). Camera traps are widely used to estimate population abundance, a key aspect of wildlife monitoring and management. Traditional methods for population estimation include driven counts, strip counts, line transects, removal methods, and capture-mark-recapture techniques. Camera trapping integrates with the mark-recapture approach employing Petersen estimators to derive population size estimates [33]. Traditional methods for identifying nest predators rely on physical evidence, such as eggshell fragments, hair, scat, or tracks. However, these approaches are often subjective, time-consuming, and may overlook instances of predation by multiple predators. In addition, the human activity required to collect such evidence can alter nesting behavior or deter certain predators, compromising the research objectives. Camera traps have become a preferred tool for many researchers, as they offer detailed insights into predation events, predator identification, and the timing of predation [33].

Understanding the patterns of daily and seasonal activity of wildlife is crucial to understanding the ecology of species. Such activity data also help to examine interspecific and intraspecific interactions, as well as predator-prey dynamics [33]. While radio-tags are commonly used for this purpose due to their ability to provide large datasets remotely and in real time [16], this method can be invasive, costly, labor-intensive, and less feasible for studying elusive species. In contrast, camera trapping offers a non-invasive alternative for studying activity patterns. The time-stamped images captured by camera traps provide reliable data on activity and behavior. Studies have revealed that this method can produce more accurate estimates of kill rates compared to traditional techniques, offering valuable information on species diets [13]. Furthermore, monitoring wildlife activity patterns through camera traps can help mitigate human-wildlife conflicts and reduce wildlife damage. Figure 3 shows the examples of the detection and classification of wildlife species using machine learning approaches. Sentinel-2 imagery has been extensively utilized for studies in Antarctica, particularly focusing on the years 2016, 2018, and 2019 [29]. The imagery was accessed via ESA's Sentinel Playground, a cloud-based platform that allows efficient examination of large datasets using various band combinations. This platform eliminates the need for time-consuming data downloads, significantly streamlined the process of identifying emperor penguin colonies in Antarctica [4]. The review process involved manually examining Sentinel-2 images on a scale of 1 : 50, 000 (equivalent to the 500 m scale in Sentinel Playground) to detect small areas with brown pixels indicative of guano staining in penguin colonies. The combination of colors in the infrared band (8, 3, 2) was particularly useful due to the high contrast between guano and sea ice. To further enhance contrast, custom settings were applied (return [B080.8, B040.8, B03 * 0.8]). Furthermore, the combination of the SWIR band (12, 8A, 4) was used to confirm the presence of guano, taking advantage of its strong reflectivity in the short-wave infrared [6]. Targeted locations were reviewed using every available image with less than 50% cloud cover between August and December. For untargeted locations, fewer images were analyzed. Suspected colonies were verified by cross-referencing additional images from the archive, ensuring reliable identification. Targeted search parameters: The identification of undiscovered penguin colonies was guided by three key parameters derived from the distribution patterns of previously known colony locations. These colonies are generally spaced at regular intervals around the Antarctic continent, with an average separation distance of approximately 311 km[29].



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1. The search for undiscovered emperor penguin colonies focused on analyzing gaps in the circumpolar distribution of known colonies. Priority was given to regions with the largest gaps, particularly along the coastlines of major ice shelves and the northern Antarctic Peninsula, which are generally unsuitable for colony establishment. Two primary criteria were used to identify potential gaps: distances exceeding 500 km and those greater than 400 km [9].

2. Previous records and references have reported several suspected emperor penguin colonies; however, these colonies were never confirmed, likely due to their small size and the limitations of Landsat imagery with 30 m pixel resolution [18]. Recent advancements in very high-resolution (VHR) satellite imagery have enabled the confirmation of some of these colonies, including those at Shackleton Ice Shelf, Jason Peninsula, and Bowman Island.

3. Emperor penguin breeding sites can be classified into four distinct groups based on geographic features (as shown in Table 3) [23]. The targeted breeding locations include:

- Windward side of bays, headlands, glacier tongues, and ice shelves: This is the most common location for colonies, with over half of all known colonies (30 out of 54) showing a preference for this habitat.
- Land-fast ice within small island archipelagos: Five colonies, with an additional two conforming with group A, exhibit this characteristic.
- Semi-permanent ice creeks: Five colonies, primarily around Droning Maud Land, share this trait.

Estimating the population size of individual emperor penguin colonies using a single Sentinel-2 image presents significant challenges. To address this, multiple images were analyzed to assess the variability and extent of guano staining associated with the colonies [25]. While remote sensing has proven to be a valuable tool for population assessments in remote regions, previous studies using Very High-Resolution (VHR) satellite imagery have reported substantial variations in the quality of population counts. Table 3 presents information on the locations of newly discovered and rediscovered emperor penguin colonies. For each colony, it includes details such as the place name, latitude, longitude, habitat type, status (newly discovered or rediscovered), and the count of habitats. The data identifies a total of 11 colonies, comprising 5 rediscovered and 6 newly discovered sites. Estimating Very High Resolution (VHR) satellite image faces several challenges, including variations in image quality, sun angle, atmospheric conditions such as clouds, shadows from icebergs or ice walls, changes in the density and distribution of huddles, and the extent of guano staining [39]. These challenges also affect medium-resolution satellite imagery, such as that captured by Sentinel-2. Previous studies have relied on comparisons with the sizes of known colony populations to provide an initial assessment of new populations. The study underscores the need for higher-resolution imagery and more precise surveys to improve accuracy. Furthermore, due to the natural annual variability in colony populations, a comprehensive understanding of new populations may require analysis over several years using VHR satellite data. Three emperor penguin colonies, previously unconfirmed, were identified during the study [30]. However, these colonies were located several kilometers away from their initially reported positions. Specifically, the Yule Bay colony was 13 km west of its reported location, Karelin Bay was 11 km farther north, and Casey Bay was 50 km northwest but still within the boundaries of Casey Bay. These rediscovered colonies were described as small and difficult to distinguish, with only a few brown pixels (> 20) visible in the satellite imagery. Confirming the presence of colonies at Yule Bay and Karelin Bay required analysis of multiple satellite images. The estimated populations at these sites are thought to be small, likely comprising a few hundred birds or fewer at each location. Figure 4 illustrates examples of these colonies as observed in Sentinel-2 imagery. Additionally, the study reported the discovery of several new emperor penguin colonies [32]. Newly discovered (red circles) and re-discovered colonies (yellow squares), in relation to previously known colony locations (green triangles). The dark blue triangles are sites thought to be no longer extant [39]. The discovery of 11 additional emperor penguin colonies, a 20% increase in breeding sites, highlights the species' population dynamics. Despite this, their small size contributes only a 5–10% rise in the global population, with many colonies requiring multiple Sentinel-2 images for confirmation due to the 10-meter resolution limitation [29]. Offshore colonies, such as Ninnis Bank (180 km offshore), demonstrate adaptability



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to non-coastal habitats, persisting over two years [34]. However, smaller colonies face higher energy demands and exposure, raising concerns about their long-term viability [38]. The absence of previously known colonies, such as Lazarev Ice Shelf (last seen in 2014), suggests vulnerability to environmental changes, including early sea ice breakup [41]. Proximity to climate-affected regions indicates that an increasing proportion of the global population may face risks from climate change, emphasizing the need for sustained monitoring and research [43]. In wildlife conservation and animal ecology, managing large data streams is essential for accurate population estimates, understanding behaviors, and addressing threats like poaching. Machine learning (ML) and deep learning (DL) enable scaling studies globally, with notable successes using advanced sensors and ML tools, such as Wildlife Insights and DeepLabCut. Despite progress, there is significant scope for innovation in hybrid models and large-scale habitat distribution modeling, highlighting the need for interdisciplinary research to advance this field further.

METHODOLOGY

Training and validating the Convolutional Neural Network model

Convolutional Neural Networks (CNNs), a type of feed-forward neural network used to process large-scale images by leveraging their local and global features. For instance, authors in [15] trained a CNN to detect elephants in satellite imagery using a dataset comprising 188 sub-images from nine different sources. Their training set included 1,270 labeled instances of elephants, representing 1,125 unique individuals. This approach highlighted the effectiveness of CNNs in identifying and classifying objects in complex and diverse image datasets. As described in [12], Test Orthomosaic 1 was divided into 274 non-overlapping tiles, each measuring 800×600 pixels. These tiles were annotated with point labels using AIDE5 software. This dataset was used to measure the manual effort required for annotating birds by hand and to evaluate the performance of a machine learning model for bird detection. A deep Convolutional Neural Network (CNN) was utilized for bird detection. The convolution operation involves sliding filters of a predefined size over an image and calculating the dot product at each position. The values of these filters are adjustable parameters learned by the model through backpropagation. Convolution can also be applied selectively at every second position, reducing the output dimensions to half the width and height of the input [14]. Max pooling is another operation used for spatial downsampling, which helps the model become invariant to translations. Additional operations, such as instance normalization and Rectified Linear Unit (ReLU) activation, are applied after each convolutional layer to enhance the network's performance. In this work, the standard ResNet architecture was modified by replacing its final two layers with custom 1×1 convolution layers. These layers first reduce the output to 1024 channels and then map it to three specific classes, as indicated by the dotted rectangles. To train a high-capacity CNN with limited training data, a subset of image patches from five orthomosaics was randomly selected for each bird species. Users annotated a total of 600 points across three bird species [20], a task manageable within a reasonable timeframe. A target of 200 points per species was set to evaluate the feasibility of this approach. However, experiments with fewer points proved to be unreliable. As described in [21], we process each point individually (solid yellow) and identify all other ground truth points (dashed yellow) within an eight-grid-cell radius. Next, we draw a convex hull around the selected points and expand it using a 3×3 square filter. Figure 6 shows an example of detecting birds using CNN. As noted in [22], the model often misclassified birds located in the middle of flocks. To address this, prior knowledge was applied during post-processing using a Markov Random Field (MRF). MRFs use a graph structure to minimize global energy across its vertices and edges. Higher energy indicates predictions that conflict with the prior knowledge. Figure 7 shows the precision recall graphs obtained in [22] by using MRF for bird detection. The graphs show the total variation of the models trained on three sets of training patches (shaded) and the average performance (dashed). The left figure shows results with just NMS, and the right with NMS and a pairwise MRF on the predicted points.





RESULT

The CNN demonstrated in [17] an overall F2 score of 0.75, with better performance in heterogeneous areas (0.778) compared to homogeneous areas (0.73). This high accuracy closely aligns with human detection capabilities, highlighting the CNN's effectiveness across diverse landscapes. To evaluate the trained CNN model's applicability to new regions, it was tested without further training on a known elephant population in the Maasai Mara, Kenya [19]. In a 0.3 sq. km image, the model successfully identified 32 elephants, demonstrating its robustness and adaptability to different environments. Variations in animal poses and sizes can impact detection accuracy. To address this, models trained on images depicting wildlife in diverse poses and sizes were found to improve adaptability and performance across species [24]. The Sahelian Upwelling Marine Ecoregion provides critical habitats for seabird populations, though suitable breeding grounds are limited to a few locations along the West African coast [35]. Studying bird species in these areas is crucial for understanding ecosystem health and biodiversity [5]. Images of breeding colonies were captured using a DJI Phantom 4 Pro drone. The UAV survey team included a pilot and a visual observer who monitored bird behavior before and during the flight [7], [8]. Observations confirmed that birds were rarely disturbed by the UAV, ensuring minimal impact on their natural behavior. CNN performance varied across species. Caspian terns exhibited lower precision and significantly reduced recall, while gulls showed inconsistent results, with precision at high recall varying between 32% and 70% without using a Markov Random Field (MRF) [27]. Manual annotation involved five annotators labeling 274 patches, resulting in 21,066 point annotations over 20 days and 16 hours, averaging 1.19 seconds per annotation [28]. While CNNs effectively identified high-density flocks of royal terns, confusion with visually similar species, such as Caspian terns, remained a challenge. Machine learning applications led to the discovery of 11 previously unidentified emperor penguin colonies using the latest satellite imagery [29]. These colonies, located in the Peninsula Region, West Antarctica, and East Antarctica, include two on ice shelves and two offshore sites.

CONCLUSION AND FUTURE WORK

This research highlights the advancements in wildlife monitoring using machine learning techniques, particularly deep learning. Abundance mapping has significantly improved the estimation of animal populations through imaging sensors such as camera traps and drones. Individual animal re-identification, essential for long-term monitoring, has become more feasible with the use of machine learning and computer vision, offering efficient alternatives to traditional methods like DNA profiling. Additionally, animal synthesis and reconstruction using 3D modeling provides valuable insights into an animal's health and behavior. Reconstructing the environment in which animals live, through satellite remote sensing, is crucial for understanding wildlife behavior and conserving ecosystems. Looking ahead, future research can focus on improving models for animal detection, re-identification, and environmental reconstruction. Incorporating larger datasets, enhancing algorithm accuracy, and exploring new sensor technologies will further advance wildlife monitoring and contribute to better-informed conservation efforts.

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Table.1: Detail study of sensors used in Digital Wild life conservation

Name	Use	Type	Task	Count
iNaturalist	Global	Human photographers	Classification detection	132
SAVMAP	Kuzikus reserve,Namibia	UAV images	Detection	152
Zooniverse	Global	Images,text,video	Classification detection	153
iRecord	United Kingdom	Photographic records	Classification	154
Great Grevy's Rally	Northern Kenya	Safari pictures	Classification detection identification	92

Table.2:List of satellite images used in the training and test dataset [1]

Date of acquisition	Satellite	Elephants labels in training dataset	Elephant labels in validation dataset	Elephant labels in test dataset
01-12-2014	WV3	197	52	10
29-01-2016	WV3	178	9	11
10-02-2016	WV3	259	19	32
03-04-2017	WV3	26	19	5
22-11-2017	WV4	10	0	0
11-01-2018	WV4	117	0	23
27-03-2018	WV4	236	16	24
08-10-2018	WV4	119	1	59
20-01-2019	WV3	22	0	0
11-08-2009	GeoEye-1	0	0	32

Table.3:The locations of newly discovered and rediscovered emperor penguin colonies found in this analysis.

SL No.	Place	Latitude	Longitude	Type of Habitat	Status	Count of Habitat
1	Yule Bay	-70.7161	166.4777	A	Rediscovered	29
2	Karelin Bay	-66.4118	85.38361	A	Rediscovered	3
3	Casey Bay	-67.312	46.957	A	Rediscovered	23
4	Verdi Inlet	-71.5559	-74.7603	A	Discovered	9
5	Cape Gates	-73.6609	-122.697	A	Discovered	8
6	Cruzen Island	-74.7235	-140.357	A	Discovered	12
7	Ninnis Bank	-66.7229	149.677	D	Discovered	13
8	Porposoise Bay	-66.3204	129.7496	A	Discovered	8
9	Cape Darlington	-71.8872	-60.1338	E	Discovered	14
10	Cape Poinsett	-65.7817	113.2351	A	Discovered	16
11	Pfrogner Point	-72.5687	-89.9058	E	Discovered	18





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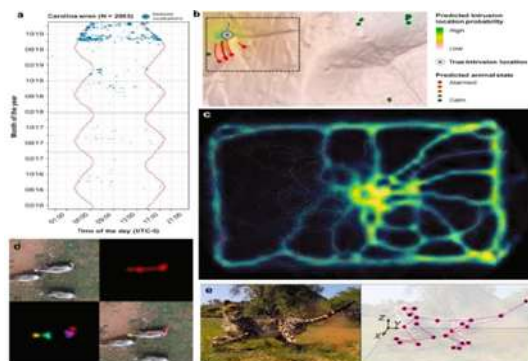


Figure. 1: Examples of research acceleration by machine learning-based systems in animal ecology [35]

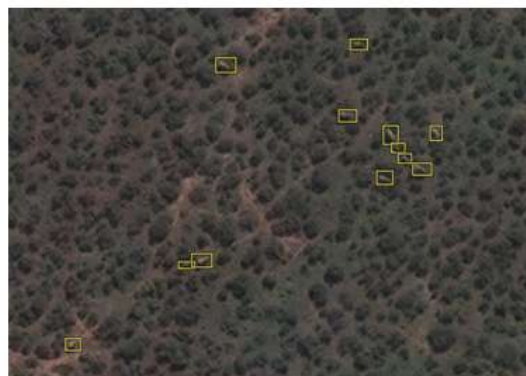


Figure. 2: An Example of the satellite image [35] showing the elephant labels in a heterogeneous area at Addo Elephant National Park, South Africa.



Figure. 3: Detection and classification of wildlife species using Faster-RCNN+ Inception-Res-Net V2 network [33] - examples of correct classification (upper images) and none detection (two hidden wild boars) and incorrect classification ("brown bear" instead of "cat") (lower images).

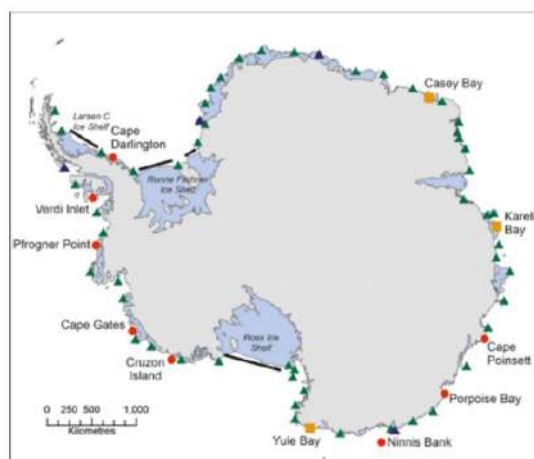
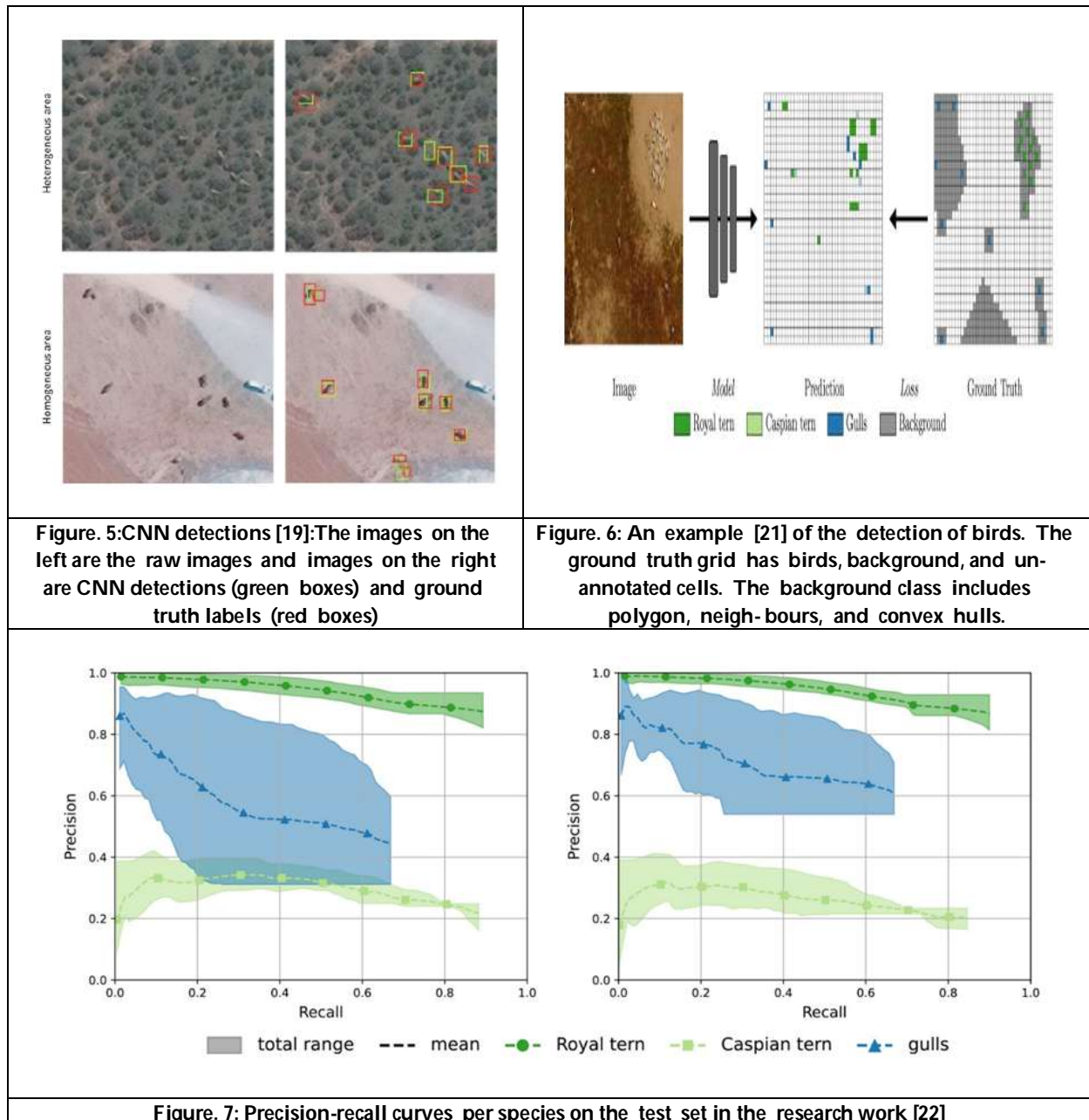


Figure. 4: Newly discovered and rediscovered emperor penguin colonies found using Sentinel2. Newly discovered (red circles) and rediscovered colonies (yellow squares), in relation to previously known colony locations (green triangles). The dark blue triangles are sites thought to be no longer extant [39].







RESEARCH ARTICLE

Molecular Characterization and Industrial Applications of a Cellulolytic Sundarban Mangrove Isolate *Bacillus licheniformis* GD2

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ABSTRACT

Lignocellulolytic biocatalysts, including laccase, cellulase, and pectinase, have significant potential for the degradation of lignocellulosic biomass (LCB). Jute and banana are types of lignocellulosic biomass (LCBs) that possess significant value owing to their capacity to generate fibers. Nevertheless, certain constituents of these plants are utilized as waste material due to their substandard fiber, leading to a negative impact on the industry. The discarded fibers can undergo a biological process to convert them into useful fiber. A bacterial strain *Bacillus licheniformis* GD2 was isolated from the Sundarban mangrove ecosystem in West Bengal, India. This strain possessed the capacity to biosynthesize several proteins. The bacteria underwent 16S rRNA sequencing investigation to identify its genetic composition. The strain exhibited the ability to produce all three crucial lignocellulolytic enzymes, with the highest levels of cellulase and minimal activity of pectinase and laccase. The strain caused substantial mechanical alteration of the fibers, as seen by the changes in Young's modulus, and successfully removed color from toxic industrial dyes. This demonstrates the significant ability of the strain to utilize waste and restore the environment. The enhanced fiber quality was confirmed through the utilization of Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM). Molecular Evolutionary Genetics Analysis version 11 (MEGA 11) was used to establish microbial phylogenetic linkages.

Keywords: *Bacillus licheniformis* GD2, Cellulase, Dye decolorization, Fiber modification, FTIR, SEM





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INTRODUCTION

Lignocellulosic waste, a key component of renewable biomass, is enzymatically degraded by enzymes like laccase, cellulase, and pectinase. These enzymes decompose complex phenols and carbohydrates in plant cell walls into simpler substances, such as sugars and aromatic compounds, with applications in various sectors. They play significant roles in bioremediation, bioethanol production, wastewater treatment, pulp and paper manufacturing, animal feed, and textiles. They facilitate the degradation of hydrocarbons and pesticides in polluted environments, thereby restoring ecosystems and reducing biological oxygen demand (BOD) and chemical oxygen demand (COD) in wastewater before release into aquatic systems [1-3]. In bioethanol production, lignocellulolytic enzymes convert cellulose and hemicellulose into fermentable sugars. In the pulp and paper industry, they expedite delignification and bleaching, reducing the environmental impact of chemical processes. In animal feed, they enhance nutrient availability and digestibility by breaking down complex carbohydrates in feedstocks like maize stover and wheat straw. In textile industries, they are vital for bio-scouring and denim bleaching, removing impurities, improving dye absorption, and enhancing fabric quality. Lignocellulolytic enzymes provide sustainable methods for biomass utilization, waste management, and the production of renewable energy and bioproducts [4]. In South Asia, enzymatic treatments are employed to transform low-grade lignocellulosic biomass (LCB) into valuable products, highlighting the economic significance of jute and banana fiber production. Cellulases facilitate the degradation of cellulose in jute and banana fibers, resulting in improved softness, flexibility, and surface characteristics. These enhancements contribute to better adherence in composites and lower energy requirements for mechanical processing. Modified fibers find applications in textiles, environmentally sustainable packaging, and composite materials, potentially acquiring antibacterial, flame-resistant, and water-resistant characteristics. Enzymatic treatment offers sustainable solutions for processing fibers into higher-value products, reducing costs and improving economic viability [5-10]. *Bacillus licheniformis* GD2, a Gram-positive bacterium isolated from Sundarban mangroves, exhibits significant cellulase activity and demonstrates versatility in bioremediation applications. The enzymes, such as cellulases, proteases, lipases, and laccases, are utilized in textiles, food, pharmaceuticals, and biofuel production. Studies on characterization indicate that cellulase derived from *Bacillus licheniformis* GD2 exhibits distinctive features characteristic of both fungal and bacterial cellulase enzymes. Research indicates that it effectively decolorizes industrial dyes and bleaches denim, providing environmentally sustainable alternatives to conventional chemical methods. Research on the application of *Bacillus licheniformis* GD2 for the modification of high root-content fibers, such as jute and banana pseudo-stem waste, is limited. This research sought to enhance the quality of these fibers through the application of advanced techniques, including FTIR, SEM, Young's modulus, and statistical analysis.

MATERIAL AND METHODS

Sample Collection

Soil and liquid samples were collected from Bidyamandir, Sundarban mangrove forest of West Bengal, India (21.9889° N, 88.7552° E). The samples were delivered to the laboratory in sterile sample bottles and zipper packs within 24 hours of collection and were stored at 4°C for further analysis.

Isolation of lignocellulolytic bacteria

The study isolated native lignocellulolytic bacteria by serially diluting (10^{-1} to 10^{-9}) soil and water samples. Bacteria were counted after 24 hours incubation at 37°C on nutrient agar plates. After screening, single colonies were streak-plated and incubated for 24-48 hours at 30°C to 37°C. Microorganisms in cellulase-selective plates were used to form pure cultures, with few colonies found in laccase and pectinase selective media. Further experiments focused on cellulase production. Most screened isolates were stored on a cellulase-selective medium at 4°C.

Qualitative and quantitative analysis of cellulolytic bacteria

Bacterial colonies were verified on Carboxy Methyl Cellulose (CMC)-agar plates through two methodologies. Initially, 100 µl of overnight-grown culture was introduced to CMC-agar plates, which were then incubated at 37°C





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for 48 hours and subsequently stained with 1% Congo red. Following a 15-minute period, the stain was removed using 1 M NaCl and subsequently rinsed with distilled water [11]. Dyes (1% Congo red, malachite green, and methylene blue) were formed. In a 100 ml conical tube, 20 ml of sterile CMC selective liquid media (containing 200 µl of dye and 200 µl of a 24-hour culture) was taken. A 2 ml sample mixture was placed in a 2 ml Eppendorf tube centrifuged at 10,000 rpm for 8 minutes. The optical density of the supernatant was measured at 497 nm, 617 nm, and 668 nm wavelengths, for up to 6 hours and was repeated every 2 hours. Selective media was used as the spectrophotometer's blank. Every two hours, the dye decolorization percentage was calculated.

Cellulase assay and kinetic study

The total cellulase activity was determined by estimating the reducing sugar released from CMC using IUPAC-recommended methods. The CMCase assay involved 0.1 ml of crude enzyme and 0.2 ml of 1% CMC in 1.7 ml of 50 mM citric acid buffer. After 60 minutes of incubation, 3 ml of 3,5-dinitrosalicylic acid (DNS) was added to stop the reaction. The amount of sugar in the supernatant was determined at 540 nm [11].

The activity of the cellulase enzyme (U/ml) = $W \times 1000 / V \times t \times M$

Here, W = the amount of released glucose

M = the molecular weight of glucose.

V = Sample volume

t = Reaction Time

The cellulase was tested for substrate specificity using substrate CMC in 0.1 M phosphate buffer at pH 4.0 to 5.0. Standard substrate glucose (concentrations ranging from 0.1 mg/ml to 1 mg/ml) served as a standard curve for enzyme experiments.

Determination of released reducing sugar from jute and banana fiber waste

This study employed a novel strain to modify waste jute and banana fibers and analyzed biopolymer composition by quantifying reducing sugars over 0, 7, 14, and 21 days. Initially, 100 ml of nutrient broth was sterilized and divided into Falcon tubes, each containing 10 ml of broth. Banana and jute fiber waste (0.1 g each) were added to designated tubes, followed by 100 µl of cellulase-producing culture. Samples were incubated for 21 days at 37°C with reciprocal agitation at 120 rpm. The microbial biomass was evaluated on days 0, 7, 14, and 21 by measuring the weight of the biomass after it had been dried. The dry weight was determined by centrifuging 2 ml of treated sample at 8000 rpm for 10 minutes. The biomass was dried at incubation temperature, and dry weight was calculated by subtracting the empty Eppendorf tube weight from the total weight. Reducing sugar levels were determined using the DNS assay, referencing a glucose standard curve as described by Kriger et al., 2020. Statistical analysis (IBM SPSS 26) validated the relationship between microbial biomass and sugar release. Controls were included: a positive control (100 µl of 0.1% commercial cellulase) and a negative control (no microbial culture or enzyme). Results standardized the methodology and confirmed the strain's efficiency in fiber modification.

FTIR analysis of treated fibers and dye decolorization

The study used Fourier transform infrared spectroscopy (FTIR) to analyze chemical changes in treated dyes, jute, and banana waste fiber. After 21 days incubation with mangrove isolate, samples were centrifuged at 12,000 rpm for 10 minutes to separate bacterial cells. The dyes were treated for 6 hours, and a portion of the liquid was vacuum freeze-dried (using EYELA, FDU-1200) until stable. The dried sample was then used for FTIR analysis, measuring spectra in the 4000-400 cm⁻¹ region using a Perkin-Elmer Frontier FTIR spectrometer.

SEM analysis

ZEISS scanning electron microscope was used at 5.00 kV to examine the modification of jute and banana waste fiber surfaces due to a cellulolytic microbial strain. The fibers were cut into small pieces and coated with silver, then placed in the SEM chamber for detailed imaging at three different magnifications: 300X, 1000X, and 5000X.



**Somnath Das et al.,****Molecular characterization**

Bacterial genomic DNA was isolated using bacterial DNA isolation kit, and the purity and concentration were assessed using a Denovix DS-11 spectrophotometer. The 16S rDNA region was amplified with Bacterial 16S rDNA PCR kit Fast (800), using *E. coli* as a positive control. An 800 bp amplicon was amplified using 16S rDNA Primer Mix and TaKaRa Taq™ HS Fast Detect Premix, followed by column purification. Bidirectional cycle sequencing was performed using forward primers and reverse primers using a BDT V3.1 Cycle sequencing kit on an ABI 3730 Genetic Analyzer. Cellulase enzyme FASTA sequences of similar bacteria with cellulase activity and positive sugar-reducing capability were retrieved from the NCBI database. The cellulase enzyme sequence was aligned using the multiple-sequence alignment method with the other bacterial cellulase sequence (from the NCBI database) through the Muscle algorithm. The phylogenetic analysis was performed using MEGA 11. The phylogenetic tree was constructed using the neighbor-joining technique. The bootstrap method assessed the consistency of the phylogenetic tree [12-15].

Statistical analysis

For statistical analysis, IBM SPSS software (version 26.0) was employed. At 0.05 significance levels (2-tailed), the Pearson correlation test and the t-test were employed to analyze the correlations between pure bacterial biomass concentration, day, and generated reducing sugar.

Pathogenicity test

The microbial isolate underwent biosafety assessment by the blood agar test. A high-quality blood agar medium was sterilized using an autoclave. Two wells were created on the agar plates, and 100 µl of a 20% hemolysin buffer was combined with 100 µl of the overnight-cultured test sample. The mixture was introduced to a separate well and kept at 30°C for 24 hours. The criterion used to assess pathogenicity was the strain's ability to cause hemolysis, which is the process of red blood cell disintegration. Bacterial colonies' capacity to cause hemolysis when cultivated on blood agar is employed to categorize specific bacteria as pathogenic.

Young's modulus

Vernier microscopes use brass steel scales that measure small changes in a material. They have a machined cast iron base covered by a metal carriage, allowing the slide to be secured in any position using a clamping screw. A vertical slide is mounted on the horizontal carriage, and a rack and pinion microscope is included. The stage has a Perspex plate and achromatic lenses, and the slides can move 210mm horizontally and 160mm vertically. The stress and strain ratio obtained using the highest weight carried by the biologically treated fibers of a fixed diameter and length was used to determine Young's modulus (E) of both the jute and banana fiber. By employing a holder to suspend the maximum weight from the fiber, the stress was calculated by dividing the force by the fiber's surface area. Strain was determined by dividing the length change by the length. After obtaining the results for both stress and strain, their ratio was used to calculate each fiber's Young's modulus and gauge how much more stretchable each was. A traveling microscope was used for all measurements [16, 17].

RESULTS AND DISCUSSION**Qualitative and quantitative screening of the mangrove isolate**

Qualitative cellulase activity of a bacterial isolate was evaluated using the Congo red CMC agar plate assay, which showed a nonhomogeneous orange clear zone surrounding the well, signaling both the cellulase and dye-decolorizing activity of the enzyme. This is crucial for the release of fermentable sugar monomers from lignocellulosic biomass. The bacterial isolates showed high cellulolytic activity, making them potential candidates for further study in industrial sectors. The dye degradation assay assessed the enzyme's ability to decolorize three dyes: Congo red, malachite green, and methylene blue. The enzyme reduced malachite green by 40% after six hours, but the Congo-red breakdown percentage was low (approximately 4%), and no breakdown was observed for methylene blue. The results suggest that dye molecules are taken up by microbial surfaces and then degraded (Fig. S2A, C).



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Dye decolorization percentage = (initial time absorbance – final time absorbance)/initial time absorbance × 100

Pathogenicity test

The GD2 isolate showed less frequent formation of halo zones on blood agar media compared to the positive control. Beta-hemolysis was used as a positive control, but the bacterial hemolysis activity was lower. The strain could be beneficial for commercialization in banana and jute fiber processing to reduce waste fiber loss, increasing economic growth in textile and fiber industries. Implementing the bacteria may not be as damaging to the ecosystem (Fig. S. 2B).

Enzyme assay and kinetic study

GD2 isolates exhibited cellulase activity of 6.57 U/ml, comparable to the positive control of commercial cellulase (6.77 U/ml), indicating the presence of necessary genes for cellulase production. The calculation of cellulase activity is as follows: GD2 Cellulase enzyme activity (U/ml) = $W \cdot 1000 / V \cdot t$. $M = (142 \times 1000) / (2 \times 60 \times 180.156) = 6.56$ U/ml

Here, W - Amount of released glucose = 141.78 μ g

M - Molecular weight of the glucose = 180.156

V - Volume of the sample = 2 ml

t - Reaction time = 60 min

Cellulase kinetic parameters ($K_m = 2.9$ mM, $V_{max} = 714.3$ mmole/min) for breaking CMC were determined using Lineweaver–Burke plots (Fig. S5D).

FTIR analysis of dye decolorization and treated waste fibers:

The CR sample treated with GD2 showed spectral peaks in the 1100–1200 cm^{-1} range, corresponding to C-N bond stretching vibrations, and in the 2900–3000 cm^{-1} range for asymmetric CH_3 group vibrations. A peak in the 2300–2400 cm^{-1} range was linked to the symmetrical and asymmetrical stretching of the tertiary amine salt. The 1300–1400 cm^{-1} range identified a carbon-nitrogen bond stretching in an aromatic tertiary amine. Biodegradation by GD2 caused breakdown of aromatic rings in the 1600–1700 cm^{-1} region, related to C=C bond stretching. For MG dye, GD2 treatment revealed benzene ring peaks (1500–500 cm^{-1}), indicating mono- and para-disubstituted benzene rings, along with C-N bond stretching at 1100–1200 cm^{-1} . FTIR spectra of the dyes also exhibited N-H stretching vibrations of primary amines between 3200–3500 cm^{-1} , suggesting MG dye decomposition by GD2. The application of GD2 to jute and banana fibers, rich in roots, removed functional groups, improving fiber quality by eliminating lignin, enhancing its economic value. Both fibers exhibited C-H, CH_2/CH_3 , and C=O vibrations in the 1380–1450 cm^{-1} and 1680–1730 cm^{-1} regions, respectively, with C-H stretching observed between 2855–3120 cm^{-1} . Detailed spectral analysis is provided in Supplementary Tables 1 and 2 (Fig. S3A-D).

SEM analysis

Scanning electron microscopy (SEM) was used to analyze the surface morphologies of waste fibers during cellulase treatment. The control surface showed smooth, minimal irregularities. After enzyme application, both waste fibers appeared to reposition and loosen the dense cellulose polymer inner core (Fig. S4A-B).

Statistical analysis

On day 21, both jute and banana fiber treatments showed a modest decrease in sugar levels, indicating a stable phase. However, microbial biomass and sugar extraction continued to increase, signifying successful retting and improved fiber quality (Fig. S6A-C). The correlation coefficient test and t-test, via IBM SPSS 26 statistical software, revealed a significant association between the biomass concentration of the cellulase-producing strain GD2, the released reducing sugar, and the day. If the p-value is positive, both variables are rising along with the first. The utilization of the cellulose segment of the fiber and the sugar released from the inner part of the fiber allows the fiber to survive for 21 days, transforming waste into economically acceptable, lustrous, soft morphological fiber with a less cellulosic component, making it perfect for the textile industry (Fig. S6A-C).



**Somnath Das et al.,****Young's modulus of the fibers**

The study reveals that microbiologically treated fibers improved their stretchability and mechanical qualities, leading to increased economic worth and development of sustainable and non-toxic commercial goods. The results show that the fiber's Young's modulus increases in the presence of lignocellulosic substrate in nutrient broth, possibly due to the multiprotein production capability of GD2 (high cellulase, low laccase, and pectinase activity). Laccase and pectinase play a crucial role in increasing the Young's modulus value. Although all morphological and physical changes are visible after cellulase treatment, the mechanical strength is only shown to be affected by the triple enzyme effect or the dual effect of laccase and pectinase, which suppresses the effect of cellulase in some respects. This could lead to the production of new sustainable and non-toxic commercial goods from these raw materials.

Molecular characterization and phylogenetic study of GD2

The Gene-Tool software program was used to create a consensus sequence of the 16S rRNA gene. This sequence was compared with NCBI GenBank database sequences via BLAST analysis, with *Bacillus licheniformis* GD2 being the most similar (100%). The 16S rRNA nucleotide sequences of *Bacillus licheniformis* GD2 were compared to cellulase-producing bacterial sequences in the databases using multiple sequence alignment method. Ten distinct cellulase sequences from bacterial species were selected, based on their cellulase activity and ability to produce reducing sugars. The MEGA 11 program was used to run 1,000 bootstrapping operations. The phylogenetic tree was constructed using the neighbor-joining technique, with residues found to be essential in the development of bacterial cellulase sequences. The coherence of the phylogenetic tree was examined using bootstrap values. The best-fit value, which correlates with high similarity between related organisms, is 100%, with good similarity up to 90% support. Consistent match rates were observed between 50% and 70% (Fig. S7.) [12, 13].

CONCLUSION

The use of lignocellulosic biomass for recycling is a promising field due to its economic viability and negative environmental impacts. Mechanical conversion methods increase costs, making them impractical. To reduce manufacturing costs, improvements in technology and processing processes are essential. This study demonstrates the effectiveness of cellulase enzymes from the mangrove isolate *Bacillus licheniformis* GD2, showing remarkable efficacy in waste processing and reutilization sectors like dyeing, textiles, and fibers. The strain can alter the characteristics of jute and banana waste fibers and break down colors rapidly, as confirmed by FTIR analysis. The isolated mangrove strain has significant potential for industrial applications, potentially resulting in higher revenue for industries employing it. Metabolic engineering, synthetic biology, and systems biology can be used to modify monoculture or consortia-based applications to enhance the effective degradation of lignocellulosic biomass on a large scale. Computer-based genetic modification on lignocellulolytic enzymes can speed up the process, enhance dye removal, improve waste treatment, and optimize waste recycling.

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Conflict of interest

There are no financial or other conflicts of interest, according to the authors.

Authors' contributions

All authors contributed equally to this research work and consented to publication in the journal.

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**Somnath Das et al.,****Data availability**

All data from this research study are presented in the manuscript and supplementary file 1.

Ethics statement

Not applicable.

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Table 1: Comparison of Young's modulus between GD2-treated and untreated Jute and Banana fibers

Biologically treated natural fiber	Microbial system used for the retting	Treated fiber diameter (mm)	Treated fiber length (mm)	Young's modulus (MPa)
Jute (Control)	GD2	0.002	90	6.02
Jute (Test fiber)		0.002	90	8.46
Banana (Control)		0.01	90	1.135
Banana (Test fiber)		0.01	90	1.249

Table. 2. FTIR analysis of treated dyes and waste fibers depending on wavenumber (WN) ranges and vibrational nature of the functional groups

After treatment with GD2	Vibration	Start WN Cm ⁻¹	End WN Cm ⁻¹	Threshold	Priority
Congo red	S=O Def	520	400	Weak	Medium
	C-S Stretch	730	665	Variable	Mandatory
	S=O Stretch	1050	1030	Variable	Mandatory
	C-H Def	1480	1420	Variable	Mandatory
	C-H Stretch	2990	2875	Variable	Mandatory
Malachite Green	C-H Def	730	690	Variable	High
	C-H Def	820	770	Variable	High
	C=C and C=N Stretch	1430	1400	Variable	Mandatory
	C=C and C=N Stretch	1485	1465	Variable	Mandatory
	C=C and C=N Stretch	1580	1560	Variable	Mandatory
	C=C and C=N Stretch	1600	1590	Variable	Mandatory
	C-H Stretch	3100	3010	Variable	Mandatory
Jute waste fiber	C-H Bend, CH ₂ /CH ₃	1450	1380	Variable	Mandatory
	C=O Stretch	1730	1680	Strong	Mandatory
	O-H Bonded, Acid	2710	2580	Variable	Mandatory
	C-H Stretch, Alkyl	3120	2855	Variable	Mandatory
Banana pseudo-stem waste fiber	Skeletal	750	705	Variable	Mandatory
	C-O Stretch, Carboxylate	1440	1360	Strong	Mandatory
	C-O Stretch, Carboxylate	1605	1560	Strong	Mandatory
	C-H Stretch, Alkyl	2975	2855	Variable	Medium

Table. 3. Functional group analysis of treated dyes and waste fibers using FTIR

Sl. No.	Analysis of the released functional groups from the GD2-treated dye, jute, and banana waste fibers.			
	Congo red	Malachite green	Jute	Banana
1	Aliphatic Sulphoxide	3-Subst Pyridine	Aliphatic Acid or Carbonyl Compound	Aliphatic Carboxylate, General
2	Unsaturated Hydrocarbon, Cyclic, > C ₅	Aliphatic Amine Salt, Secondary	Aliphatic Amine Salt, Primary, Hydrochloride	Phenyl Substituent
3	Aliphatic Alkoxy, Methoxy	Aliphatic Amine, Primary	Aliphatic Nitrite	Carbonyl, Possibly Conjugated Ketone



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4	-	Aliphatic Amine, Primary, Branched	Phenyl Substituent	Aliphatic Tertiary
5	-	Aliphatic Isonitrile	CF ₃ group	Unsaturated Hydrocarbon, Cyclic, > C ₅
6	-	Aliphatic Mercapto Group	Aliphatic Thiocyanate	Aliphatic Nitrile
7	-	Aliphatic Nitrile	Linear Bromo Compound	Aliphatic Anhydride - Carbonyl Compound
8	-	Aliphatic Nitrile, Linear Chain	Aliphatic Tertiary	Aliphatic Thiocyanate
9	-	Aliphatic Nitrite	Unsaturated Hydrocarbon, Cyclic, > C ₅	Aliphatic Isonitrile
10	-	Aliphatic Primary Amide, Linear	Aliphatic Anhydride - Carbonyl Compound	Aliphatic Acid Halide, Linear
11	-	Aliphatic Sulphoxide	Aliphatic Isonitrile	-
12	-	Aliphatic tert-Amino Acid	Aliphatic Ester, Acetate	-
13	-	Aliphatic Thiocyanate	Aliphatic Acid Halide, Linear	-
14	-	Carbonyl, Alpha Alkyl Substituted	-	-
15	-	Carbonyl, Alpha Methylene	-	-
16	-	Carbonyl, Possibly 2-Hydroxy Acid	-	-
17	-	Hydroxy, Possibly 1,2-Diol	-	-
18	-	Linear Chain	-	-
19	-	Linear Chloro Compound	-	-
20	-	Long Chain Substituent	-	-
21	-	N-MethylAmino Substituent	-	-
22	-	Possibly Primary Alcohol, Long Chain	-	-
23	-	Primary Alcohol	-	-
24	-	Tertiary Alcohol	-	-
25	-	Unsaturated Hydrocarbon, Cis Alkene	-	-
26	-	Unsaturated Hydrocarbon, Cyclic, > C ₅	-	-
27	-	Unsaturated Hydrocarbon, Simple Alkyne	-	-
28	-	Unsaturated Hydrocarbon,	-	-



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		Trisubstituted		
29	-	Unsaturated Hydrocarbon, Vinylidene	-	-
30	-	Aliphatic Acid or Carbonyl Compound	-	-
31	-	Aliphatic Amino Acid - Carbonyl Compound	-	-
32	-	Aliphatic Conjugated Primary Amide	-	-
33	-	Aliphatic Conjugated Secondary Amide	-	-
34	-	Aromatic Amide	-	-
35	-	Aliphatic Secondary Amide	-	-
36	-	Aliphatic Conjugated Carboxylic Acid	-	-
37	-	Aliphatic Primary Amide, Free NH ₂ Amino	-	-
38	-	Aromatic Subst., Acetanilide Derivative	-	-
39	-	Phenyl Substituent	-	-
40	-	Furan, 2 subst.	-	-
41	-	Linear Iodo Compound	-	-
42	-	2-Subst Pyridine	-	-
43	-	Aliphatic Acid Halide, Linear	-	-
44	-	Aliphatic Alkoxy, Methoxy	-	-
45	-	Aliphatic Mercaptan, Branched, Methyl	-	-
46	-	Carbonyl, Possibly Conjugated Aldehyde	-	-
47	-	Unsaturated Hydrocarbon, Trans Conjugated	-	-
48	-	Aliphatic Primary Amide	-	-
49	-	Aliphatic Amido, Possibly Subs. Urea	-	-
50	-	Pyridines, General	-	-
51	-	Aliphatic Nitro Group	-	-
52	-	Aliphatic Tertiary	-	-
53	-	CF ₃ group	-	-
54	-	Methyl Silanes	-	-
55	-	Unsaturated Hydrocarbon, Ether Conjugated	-	-



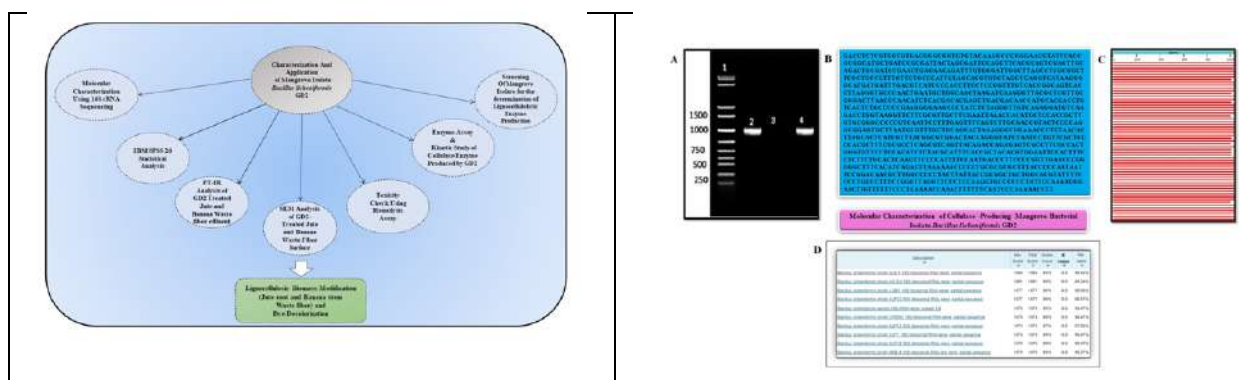


Fig.1 Graphical Abstract

Fig. S1. *Bacillus licheniformis* GD2: Molecular characterization of the mangrove strain. A. It shows a 2% agarose gel with a 1Kb 16S rRNA gene PCR result. A 16S amplicon is in lane 2 (positive control), a kilobase DNA ladder in lane 1 (one kb), a negative control in lane 3, and a sample in lane 4 (four kb). B. Consensus sequence of *Bacillus licheniformis* GD2. C. A visual breakdown of the BLAST report. D. Sequences in the NCBI database that provide substantial alignments: Max Score is the maximum alignment score for that database sequence. Total Score: the total of each segment's alignment ratings. Query Coverage is the percentage of the query in line with the database's sequence. E-Value: The anticipated value (E value) for each alignment in that database. Sequence Identity: Of all query-subject alignments, identity accounts for the largest proportion.

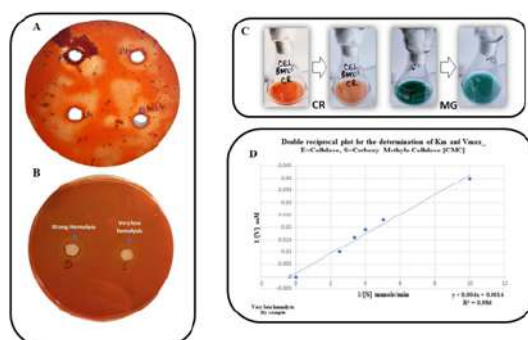


Fig. S2 A. Qualitative assay- Congo red degradation producing orange zone surrounding wells by cellulase producing GD2 strain in Congo red-CMC media. B. Hemolysis assay for pathogenicity determination of the GD2 strain C. Quantitative assay by dye degradation using Cellulase-GD2. D. Cellulase enzyme kinetics showing Km and Vmax using CMC as a substrate.





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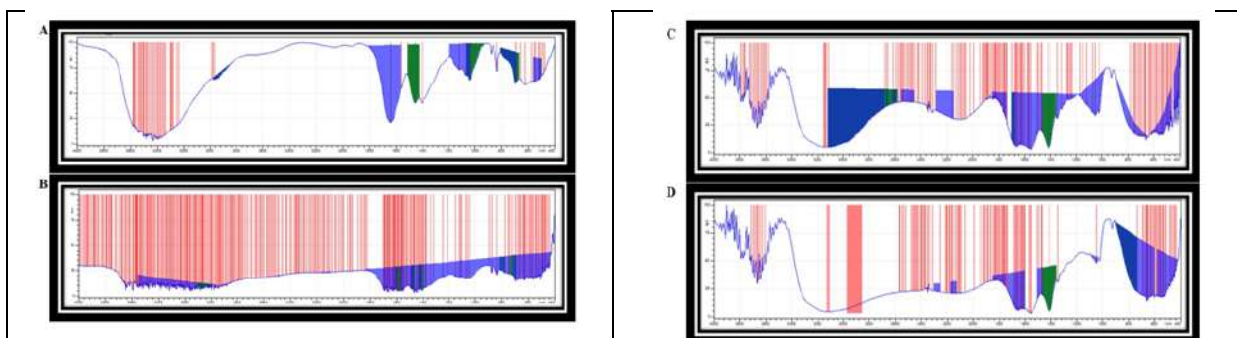


Fig. S3. FTIR analysis of dye degradation and jute and banana waste fiber modification by mangrove strain-GD2 showing different released functional groups in respective wavenumbers. A. Congo Red B. Malachite Green C. Jute waste fiber D. Banana fiber waste.

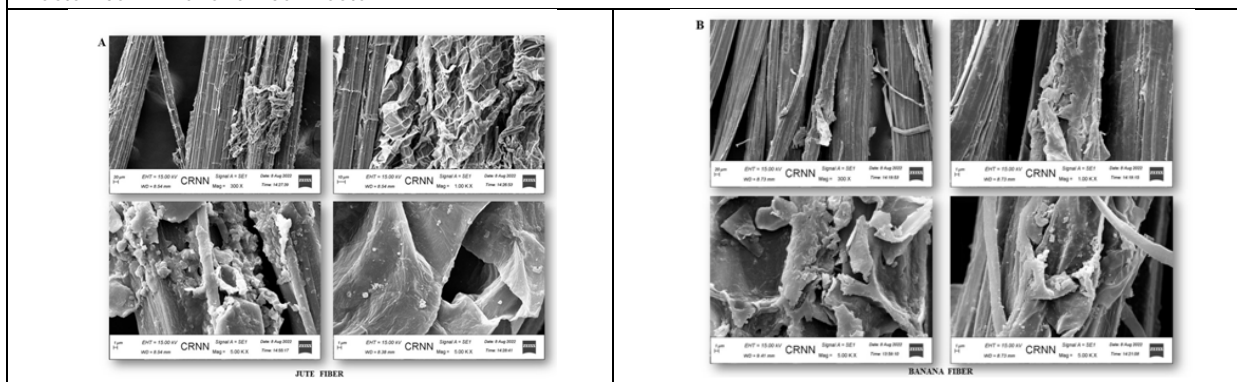


Fig. S4. Analysis of the Cellulase-GD2 treated waste fibers through Scanning Electron Microscopy showing the breakdown of the cellulose polymer that positively modifies the waste fiber quality. A. Modified jute waste fiber. B. Modified banana pseudo-stem waste fiber. Magnification: 300X, 1000X, and 5000X.

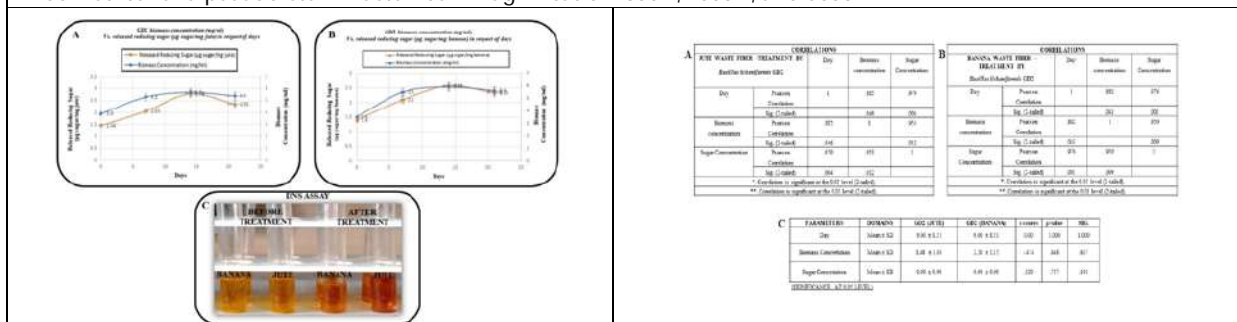


Fig. S5. Day, GD2-Biomass and released reducing sugar comparison from days 0-21 of A. Jute waste fiber treatment by GD2; B. Banana pseudo-stem waste fiber treatment by GD2. C. DNS assay showing a positive test for reducing sugar released after treatment of the waste fiber by GD2, proving the breakdown of cellulose and release of reducing sugar.

Fig. S6. IBM SPSS 26 statistical analysis, showing correlations among Day, GD2-Biomass, and released reducing sugar. A. Jute waste fiber treatment by GD2: Correlation is significant at the 0.01 level and 0.05 level (2-tailed). B. Banana pseudo-stem waste fiber: Correlation is significant at the 0.01 and 0.05 levels (2-tailed). C. Significant correlation among all three parameters justified by t score and p value.

A. JUTE WASTE FIBER TREATMENT BY GD2				
Day	GD2-Biomass	Released Reducing Sugar	Correlation	Significance
Day	GD2-Biomass	Released Reducing Sugar	0.92	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.92	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.92	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.92	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.92	0.000

B. BANANA PSEUDO-STEM WASTE FIBER TREATMENT BY GD2				
Day	GD2-Biomass	Released Reducing Sugar	Correlation	Significance
Day	GD2-Biomass	Released Reducing Sugar	0.88	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.88	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.88	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.88	0.000
Day	GD2-Biomass	Released Reducing Sugar	0.88	0.000

C. SIGNIFICANT CORRELATION AMONG ALL THREE PARAMETERS				
Parameter	Mean	SD	t-value	p-value
Day	10.00	2.00	10.00	0.000
GD2-Biomass	10.00	2.00	10.00	0.000
Released Reducing Sugar	10.00	2.00	10.00	0.000

Fig. S6. IBM SPSS 26 statistical analysis, showing correlations among Day, GD2-Biomass, and released reducing sugar. A. Jute waste fiber treatment by GD2: Correlation is significant at the 0.01 level and 0.05 level (2-tailed). B. Banana pseudo-stem waste fiber: Correlation is significant at the 0.01 and 0.05 levels (2-tailed). C. Significant correlation among all three parameters justified by t score and p value.





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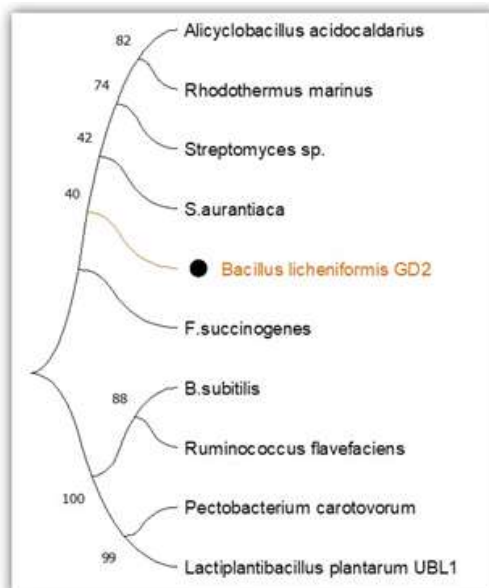


Fig. S7. Analyses of the phylogenetic tree: The evolutionary history was estimated using the neighbor-joining method. The bootstrap consensus tree calculated from 1000 iterations represents the evolutionary history of the species under study. For partitions replicated in fewer than 50% of bootstrap replicates, branch collapse occurs. The proportion of duplicate trees in which the related taxa clustered during the bootstrap test (1000 repetitions) is shown next to each branch. The maximum composite likelihood method was used to calculate the evolutionary distances expressed in base substitutions per site. This study focused on ten different nucleotide sequences. First+Second+Third+Noncoding codon locations were included. For each set of sequences, all uncertain sites were removed (pairwise deletion option). There were a total of 2468 positions in the final dataset. Evolutionary studies were performed with MEGA11. Other cellulase-producing strains from the NCBI database were compared with the GD2 strain. The supplementary files 1 contain all the FASTA sequences of the several cellulase-producing microbial strains that were compared to create the phylogenetic tree and GD2 strain's genetic characterization data respectively.





To Calculate Energy with Bond Energy of Chemical Graphs using Neutrosophic Labeling

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ABSTRACT

The purpose of this work is to explore calculate the energy and bond energy of the chemical graphs with neutrosophic labeling as numerical examples. Deneutrosophication was applied to neutrosophic chemical graphs, which gives the crisp values with the solution. This paper demonstrates energy and bond energy of chemical graphs are almost equal, while the bond energy value is converted to kilowatt hour.

Keywords: Labeling, Neutrosophic Labeling, Energy, Bond energy, Chemical Graphs.

INTRODUCTION

The energy of a graph G as a chemical concept leading to HMO theory was introduced by Hückel in 1931 and developed into a mathematical interpretation many years later by Gutman in 1978. Chemical graphs, sometimes referred to as molecular graphs, are a method of employing graph theory to depict the structure of a chemical substance. They are an essential data structure for chemical structure representation in cheminformatics. Chemical graphs are graphs with atoms represented by vertices and chemical bonds represented by edges. The type of bond and the type of atom are used to identify the edges and vertices, respectively. The physical and biological characteristics of chemical substances are modelled using chemical graphs in cheminformatics and bioinformatics. In 2009, Chandrashekar Adiga and M. Smitha conducted research on the Maximum Degree Energy of a Graph [1]. Mohammad Reza Oboudi¹ conducted research on energy and Seidel energy of graphs in 2016 [5]. In 2019, S. Satham Hussain, R. Jahir Hussain, and Florentin Smarandache created a novel idea called neutrosophic fuzzy, which they applied to ambiguous graphs[6]. Florentin Smarandache





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introduced The Score, Accuracy, and Certainty Functions in 2020, which determine the Total Order on the Set of Neutrosophic Triplets (T, I, F) [2]. Kanika Mandal on Deneutrosophication by 2020 [3]. In 2023, Katja Zemljč and Petra Žigert Pleteršek presented a new term in chemical graph theory: Smoothness of Graph Energy in Chemical Graphs [4]. In this work we present the some innovative concepts are applied in chemical graphs and calculate the energy and bond energy of a Neutrosophic fuzzy labeling chemical graph applied Deneutrosophication of Neutrosophic fuzzy Labeling chemical graph.

Methods (Definition)**Definition 1.**

A neutrosophic graph $G^* = (V, \sigma, \mu)$ is said to be an neutrosophic labeling graph if $T1 : V \rightarrow [0, 1]$, $I1 : V \rightarrow [0, 1]$, $F1 : V \rightarrow [0, 1]$ and $T2 : V \times V \rightarrow [0, 1]$, $I2 : V \times V \rightarrow [0, 1]$, $F2 : V \times V \rightarrow [0, 1]$ is bijective such that truth-membership function, indeterminacy-membership function and falsity membership of the vertices and edges are distinct and for every edges (vi, vj) ,

- (i) $T2(vi, vj) \leq \min\{T1(vi), T1(vj)\}$,
- (ii) $I2(vi, vj) \leq \min\{I1(vi), I1(vj)\}$,
- (iii) $F2(vi, vj) \leq \max\{F1(vi), F1(vj)\}$, and $0 \leq T2(vi, vj) + I2(vi, vj) + F2(vi, vj) \leq 3$.

Definition 2.

Bond energy is the amount of energy needed to break a chemical bond between atoms in a molecule.

RESULTS AND DISCUSSION**To find the Energy and Bond energy of the following Chemical graphs.**

Let us take the neutrosophic labeling of the Cyclopentane chemical graph convert into the crisp values using Single-Valued Neutrosophic Score, Accuracy, and Certainty Functions. Particularly we choose certainty function

$$c : M \rightarrow [0, 1]$$

$$(T, I, F) = T$$

Then we have to find the Energy of a Neutrosophic Labeling Cyclopentane chemical Graph.

To find the Eigen values

$$A(C_p(G)) = \begin{bmatrix} 0 & 0.01 & 0 & 0 & 0.01 \\ 0.01 & 0 & 0.01 & 0 & 0 \\ 0 & 0.01 & 0 & 0.02 & 0 \\ 0 & 0 & 0.02 & 0 & 0.03 \\ 0.01 & 0 & 0 & 0.03 & 0 \end{bmatrix}$$

$$\det(A(C_p(G)) - \lambda I) = \begin{vmatrix} -\lambda & 0.01 & 0 & 0 & 0.01 \\ 0.01 & -\lambda & 0.01 & 0 & 0 \\ 0 & 0.01 & -\lambda & 0.02 & 0 \\ 0 & 0 & 0.02 & -\lambda & 0.03 \\ 0.01 & 0 & 0 & 0.03 & -\lambda \end{vmatrix}$$

Eigen Values $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$.

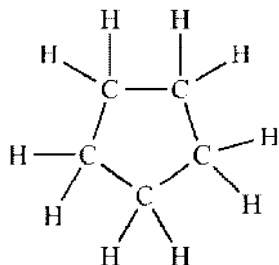
Spectrum of $(Nl(G)) = (0, 0, 0, 0, 0)$

Energy of a Neutrosophic Labeling Cyclopentane graph $E(C_p(G)) = 0 < 1$.





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Chemical Structure for Cyclopentane C_5H_{10} 

Bond Energy

$$5 (C-C) + 10 (C-H) = 5(347) + 10 (413) \\ = 5865 \text{ KJ/mol}$$

$$1 \text{ mole} = 6.0221 \times 10^{23}$$

$$\text{Bond Energy} = \frac{5865}{6.0221 \times 10^{23}} = 973.91 / 3600 \\ = 0.2705 \text{ kilowatt hour.}$$

Energy of the Cyclopentane chemical graph \leq Bond Energy of the Cyclopentane chemical graph.

$0 \leq 0.2$. Take the neutrosophic labeling of the Methylcyclopentane chemical graph convert into the crisp values using Single-Valued Neutrosophic Score, Accuracy, and Certainty Functions. Particularly we choose certainty function

$$c : M \rightarrow [0, 1]$$

$$(T, I, F) = T$$

Then we have to find the Energy of a Neutrosophic labeling Methylcyclopentane Graph.

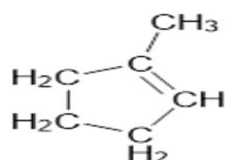
To find the Eigen values

$$A(MC_p(G)) = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.01 & 0 & 0 & 0.01 \\ 0 & 0.01 & 0 & 0.02 & 0 & 0 \\ 0 & 0 & 0.02 & 0 & 0.03 & 0.04 \\ 0 & 0 & 0 & 0.03 & 0 & 0.04 \\ 0 & 0.01 & 0 & 0.04 & 0.04 & 0 \end{bmatrix}$$

$$\det (A(MC_p(G)) - \lambda I) = \begin{vmatrix} -\lambda & 0 & 0 & 0 & 0 & 0 \\ 0 & -\lambda & 0.01 & 0 & 0 & 0.01 \\ 0 & 0.01 & -\lambda & 0.02 & 0 & 0 \\ 0 & 0 & 0.02 & -\lambda & 0.03 & 0.04 \\ 0 & 0 & 0 & 0.03 & -\lambda & 0.04 \\ 0 & 0.01 & 0 & 0.04 & 0.04 & -\lambda \end{vmatrix}$$

Eigen Values $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5 = 0$ $\lambda_6 = 0.1$

Energy of a Neutrosophic Labeling Cyclopentane graph $E(MC_p(G)) = 0.1 < 1$.

Chemical Structure for Methylcyclopentane C_6H_{10} 

**Bond Energy**

$$5(\text{C}-\text{C}) + 10(\text{C}-\text{H}) + (\text{C}=\text{C}) = 5(347) + 10(413) + 614$$

$$= 6479 \text{ KJ/mol}$$

$$1 \text{ mole} = 6.0221 \times 10^{23}$$

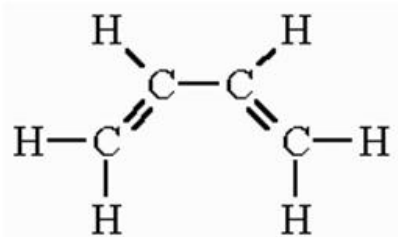
$$\text{Bond Energy} = \frac{6479}{6.0221 \times 10^{23}} = 1075.87 / 3600$$

$$= 0.2988 \text{ kilowatt hour.}$$

Energy of the Methylcyclopentane chemical graph $0 \leq 0.2$ bond Energy of the Methylcyclopentane chemical graph.

Butadiene C_4H_6

Then we have to find the Energy of a Neutrosophic labeling Butadiene Graph.

Chemical structure of Butadiene C_4H_6 **Bond Energy**

$$4(\text{C}-\text{C}) + 6(\text{C}-\text{H}) + (\text{C}=\text{C}) = 4(347) + 6(413)$$

$$= 3866 \text{ KJ/mol}$$

$$1 \text{ mole} = 6.0221 \times 10^{23}$$

$$\text{Bond Energy} = \frac{3866}{6.0221 \times 10^{23}} = 641.96 / 3600$$

$$= 0.1783 \text{ kilowatt hour.}$$

Energy of the Butadiene chemical graph \leq Bond Energy of the Butadiene chemical graph. $0 \leq 0.1$.

Benzene C_6H_6

Then we have to find the Energy of a Neutrosophic labeling Benzene Graph.

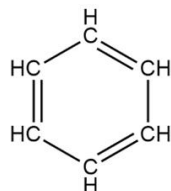
$$\text{Adjacency Matrix } A((\text{Be})) = \begin{bmatrix} 0 & 0.02 & 0 & 0 & 0 & 0.03 \\ 0.02 & 0 & 0.03 & 0 & 0 & 0 \\ 0 & 0.03 & 0 & 0.04 & 0 & 0 \\ 0 & 0 & 0.04 & 0 & 0.05 & 0 \\ 0 & 0 & 0 & 0.05 & 0 & 0.06 \\ 0 & 0 & 0 & 0 & 0.06 & 0 \end{bmatrix}$$

$$\text{Det } (A((\text{Be}) - \lambda I)) = \begin{vmatrix} -\lambda & 0.02 & 0 & 0 & 0 & 0.03 \\ 0.02 & -\lambda & 0.03 & 0 & 0 & 0 \\ 0 & 0.03 & -\lambda & 0.04 & 0 & 0 \\ 0 & 0 & 0.04 & -\lambda & 0.05 & 0 \\ 0 & 0 & 0 & 0.05 & -\lambda & 0.06 \\ 0 & 0 & 0 & 0 & 0.06 & -\lambda \end{vmatrix}$$

Eigen Values $\lambda_1 = -0.1, \lambda_2 = 0, \lambda_3 = 0, \lambda_4 = 0, \lambda_5 = 0, \lambda_6 = 0.1$.

Energy of the Neutrosophic Labeling Benzene chemical graph is 0.



**Chemical Structure of Benzene****Bond Energy of Benzene**

$$\begin{aligned}
 3(\text{C}-\text{C}) + 3(\text{C}=\text{C}) + 6(\text{C}-\text{H}) &= 3(347) + 3(614) + 6(413) \\
 &= 5361 \text{ KJ/mol.} \\
 &= \frac{5361}{6.0221} = 890.22 \times 10^{-23} \\
 &= 0.247 \text{ Kilowatt hours.} \\
 &= 0.3 \text{ Carbon Bonds.}
 \end{aligned}$$

Molecule Graph**Ethylene**

Then we have to find the Energy of a Neutrosophic labeling Benzene Graph.

$$\text{Adjacency Matrix } A((E)) = \begin{bmatrix} 0 & 0 & 0.02 & 0 & 0 & 0 \\ 0 & 0 & 0.03 & 0 & 0 & 0 \\ 0.02 & 0.03 & 0 & 0.04 & 0 & 0 \\ 0 & 0 & 0.04 & 0 & 0.05 & 0.05 \\ 0 & 0 & 0 & 0.05 & 0 & 0 \\ 0 & 0 & 0 & 0.05 & 0 & 0 \end{bmatrix}$$

$$\text{Det } (A((E)) - \lambda I) = \begin{vmatrix} -\lambda & 0 & 0.02 & 0 & 0 & 0 \\ 0 & -\lambda & 0.03 & 0 & 0 & 0 \\ 0.02 & 0.03 & -\lambda & 0.04 & 0 & 0 \\ 0 & 0 & 0.04 & -\lambda & 0.05 & 0.05 \\ 0 & 0 & 0 & 0.05 & -\lambda & 0 \\ 0 & 0 & 0 & 0.05 & 0 & -\lambda \end{vmatrix}$$

Eigen Values $\lambda_1 = -0.1, \lambda_2 = 0, \lambda_3 = 0, \lambda_4 = 0, \lambda_5 = 0, \lambda_6 = 0.1$.

Energy of the Neutrosophic Labeling Ethylene chemical graph is 0.

Chemical Structure of Ethylene C_2H_4

$$\begin{aligned}
 4(\text{C}-\text{H}) + (\text{C}=\text{C}) &= 4(413) + 614 \\
 &= 2266 \text{ KJ/mol} \\
 &= 376.28 \times 10^{-23} \\
 &= 0.104 \times 10^{-23} = 0.1 \text{ only one carbon Bond.}
 \end{aligned}$$

CONCLUSION

In this Paper, then the adjacency matrix and energy of the chemical graphs are determined. At the same time, the energy of the graph almost equal to the bond energy of the Chemical graphs. Finally, this research revealed the simplest way for calculating the energy of chemical graph, which is the neighbouring matrix method. The Neutrosophic fuzzy values of chemical graphs were then deneutrosophicated to provide crisp values. In this way easily find the carbon bonds in the chemical graphs.





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Table.1 : Neutrosophic labeling Numbers to certainty (or) Crisp Values.

Vertices/Edges	Neutrosophic Labeling Numbers	Crip values
a	(0.01,0.02,0.03)	0.01
b	(0.02,0.03,0.04)	0.02
c	(0.03,0.04,0.05)	0.03
d	(0.04,0.05,0.06)	0.04
e	(0.05,0.06,0.07)	0.05
ab	(0.01,0.02,0.04)	0.01
bc	(0.01,0.03,0.05)	0.01
cd	(0.02,0.03,0.06)	0.02
de	(0.03,0.04,0.07)	0.03
ea	(0.01,0.02,0.07)	0.01

Table.2: Neutrosophic labeling Numbers to certainty (or) Crisp Values.

Vertices/Edges	Neutrosophic Labeling Numbers	Crip values
a	(0,0.02,0.03)	0
b	(0.01,0.03,0.04)	0.01
c	(0.02,0.04,0.06)	0.02
d	(0.03,0.05,0.07)	0.03
e	(0.04,0.06,0.08)	0.04
f	(0.05,0.07,0.09)	0.05
ab	(0,0.01,0.04)	0
bc	(0.01,0.03,0.04)	0.01
cd	(0.02,0.03,0.07)	0.02
de	(0.03,0.04,0.08)	0.03
ef	(0.04,0.06,0.09)	0.04
fa	(0.01,0.03,0.09)	0.01





<p>Figure 1 : Cyclopentane C₅H₁₀</p>	<p>Figure.2 : Butadiene chemical graph with Neutrosophic Labeling</p>
<p>Figure.3: Benzene chemical graph with Neutrosophic Labeling</p>	<p>Figure.3.1 :Neutrosophic Labeling Benzene chemical graph with crisp values</p>
<p>Figure.4: Ethylene chemical graph with Neutrosophic Labeling</p>	<p>Figure.4.1 : Neutrosophic Labeling Ethylene chemical graph with crisp values</p>





Malpractices in Regulatory Submissions (MRS)

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ABSTRACT

Malpractices in regulatory submissions (MRS) This study looks at unethical practices in regulatory submissions from the healthcare and pharmaceutical industries, highlighting how important ethical standards and data integrity are to gaining regulatory approval and maintaining public confidence. Data fabrication and falsification, concealing important information, unethical research techniques, conflicts of interest, data misrepresentation, plagiarism, and quality identification failures are the seven main forms of misconduct that are identified. The paper emphasizes the negative impacts of these activities on public health, regulatory deadlines, and institutional credibility by analyzing statistical data and historical cases from regulatory agencies including the FDA and CDSCO. It also examines the roles that regulatory bodies play in addressing these problems and suggests ways to improve submissions' ethical conduct and openness. In the end, the study emphasizes the necessity of strict regulation to guarantee that health-related items fulfil safety and effectiveness requirements, safeguarding patient welfare and maintaining public trust in healthcare systems.

Keywords: Malpractices; Regulatory submissions; Plagiarism; Data fabrication; Conflict of interest; Unethical Research Practices; Data falsification.

INTRODUCTION

This study aims to explore common malpractices in regulatory submissions, specifically focusing on the pharmaceutical and healthcare sectors where the integrity of data, ethical standards, and accuracy in submissions are essential for regulatory approval, patient safety, and public trust. The study reviews seven primary areas of misconduct: data fabrication and falsification, withholding information, unethical research practices, conflicts of interest, data misrepresentation, plagiarism, and failures in quality identification. Each area of malpractice is

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analyzed to understand its impacts on regulatory outcomes, product approval timelines, and the broader implications for public health. Additionally, the study seeks to highlight the consequences of these malpractices, ranging from reputational damage to legal ramifications, and discusses the role of regulatory bodies, such as CDSCO, in identifying and mitigating these issues to ensure high standards in product development and market introduction. Through this analysis, the study aims to promote ethical practices and reinforce the importance of transparency, quality, and integrity in regulatory submissions. Common malpractices in regulatory submissions include data fabrication and falsification, withholding of information, unethical research practices, and conflicts of interest, misrepresentation of data, plagiarism, and failure in quality identification.

Data Fabrication and Falsification**Data Fabrication**

This refers to the intentional creation of false data or manipulation of research results. It is a serious ethical violation in scientific research, academic settings, and industries like pharmaceuticals and healthcare, where data integrity is crucial for regulatory compliance, patient safety, and public trust.

Data Falsification

This entails falsifying study data to create a misleading impression. Some unethical approaches include eliminating outliers or uncomfortable results, editing, adding, or missing data points to create a misleading narrative, and manipulating pictures such as micrographs, gels, and radiological images to misrepresent conclusions. A false scientific record that does not accurately reflect the current level of scientific knowledge can result from both fabrication and falsification.(2, 3)

Withholding Information

Assessments and certifications may lose their legitimacy if information is withheld in regulatory filings. Intentional or inadvertent, this misconduct can have dire repercussions. If an organization is proven to have engaged in malpractice, it could lose its accreditation and suffer reputational harm. It may cause delays in the approval process, which could affect the introduction of new goods or services and, in turn, market access and competitive advantage.(4)

Unethical Research Practices

Data fabrication, coercion, and lack of informed consent are examples of unethical research procedures. To preserve the integrity of research findings and safeguard the rights and welfare of participants, these methods must be avoided. Additionally, unethical activities include publishing-related malpractices like authorship problems and anomalies in ethical clearance, as well as methodological malpractices including selective use of data, out-of-date protocols, and deliberate manipulations. As seen by Paolo Macchiarini's case, when unethical research resulted in the loss of lives, these techniques can have serious repercussions. (5).

Conflict of Interest

When it comes to regulatory submissions Person or entity has several interests that could influence their decision-making and jeopardize their core responsibilities, such as patient safety or scientific integrity, this is known as a conflict of interest (COI).An individual or organization is said to have a conflict of interest when they have many financial, personal, or professional interests that may compromise their ability to act impartially. According to this, secondary interests could sway the process of making judgments about regulatory submissions, leading to choices that put those interests ahead of the primary duty to ensure public health and safety.(5,6)

Plagiarism

The act of using another person's words, ideas, or work and presenting them as one's own without proper acknowledgement" is the standard definition of plagiarism. It is one of the most prevalent forms of scientific misconduct seen in scholarly and research articles. This essay aims to give a comprehensive explanation of



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plagiarism, including its various forms, consequences, and detection methods, in order to raise awareness of the importance of maintaining academic integrity and avoiding unethical research practices.

One type of research misconduct is plagiarism, which includes behaviors like fabricating results, altering data, misrepresenting findings, drawing biased conclusions, and using someone else's ideas or material in a study report without giving proper credits. Although plagiarism and copyright infringement sometimes overlap, plagiarism is still essentially an ethical problem.(7)

METHODOLOGY

This article reviews malpractices in regulatory submissions by examining data and case studies from the pharmaceutical and healthcare industries. The study follows a qualitative approach, using secondary sources from regulatory bodies such as the FDA, CDSCO, and WHO, alongside peer-reviewed journals, to highlight common unethical practices like data fabrication, withholding information, and conflicts of interest. Data validation included cross-referencing sources and reviewing FDA and CDSCO inspection reports to ensure accuracy. To explore the impact of conflicts of interest on regulatory submissions, the study draws from documented cases where undisclosed conflicts influenced decision-making. Ethical issues, including informed consent violations and the role of quality control failures, were examined through examples of withdrawn drugs and the repercussions on public trust and safety. Statistical software was employed to analyze trends in Form 483 issuance, while qualitative analysis focused on interpreting ethical breaches and regulatory responses. By synthesizing these findings, the article proposes measures for improving transparency, integrity, and regulatory oversight in submissions.

RESULTS

1. Here are some observations from the data(9)

Form FDA 483 is not only specifically issued for malpractices in regulatory submissions. Also, it is issued by the U.S. Food and Drug Administration (FDA) to document inspectional observations made during an inspection of a facility. These observations typically pertain to deviations from Current Good Manufacturing Practices (CGMP), quality system failures, or other compliance issues related to FDA regulations. While Form 483 typically addresses operational or quality-related issues observed during facility inspections, data integrity violations (e.g., falsified records) uncovered during inspections can indirectly impact regulatory submissions if they rely on compromised data. Malpractices in regulatory submissions themselves (e.g., submission of false or misleading information) fall under other FDA action.

1. There's a clear increase in the number of Form 483s issued over the years.

2. 2024 has the highest number of Form 483s issued (53), accounting for the largest slice of the pie. (up to the current point in the year).

3. 2020 and 2021 have significantly fewer Form 483s compared to the later years.

4. There's a substantial jump from 2021 (9 forms) to 2022 (31 forms).

2. Shows the number of FDA warning letters issued each year from 2020 to 2024(10)

2020: 639 warning letters were issued.

2021: The number increased to 688, marking the highest level in this period.

2022: The number remained the same at 688.

2023: The number of warning letters dropped to 599, indicating a decrease.

2024: There has been a further decline to 433 warning letters issued (up to the current point in the year).

FDA warning letters peaked in 2021 and 2022, and have been declining since then, with 2024 showing the lowest number so far in this five-year period.

The warning letters that occurred due to the failure in the quality identification, data fabrication, failure to follow the gmp guidelines.





DISCUSSION

Case study1: Quality failure of the drug to the company Omni Lens Pvt. Ltd

Owing to serious flaws in its Quality Control Unit (QU), Omni Lens Pvt. Ltd. was unable to adhere to CGMP rules. As stated in 21 CFR 211.22, the QU failed to ensure that the identity, strength, quality, and purity standards were met. The company failed to establish appropriate oversight of its contract manufacturing organizations (CMOs) and lacked a sufficient QU to supervise the production of over-the-counter drug items. The corporation jeopardized CGMP compliance by giving CMOs crucial QU responsibilities, which led to insufficient oversight over manufacturing processes. A CMO's shortcomings included a badly planned aseptic processing room and the lack of crucial validation tests including benzalkonium chloride efficacy testing and dynamic airflow visualization. Additionally, Omni Lens misbranded items including "Green Glo," "BioGlo," and "Vista Gonio Eye Lubricant" by breaking section 510 of the FD&C Act's requirements for establishment registration and drug listings. Under section 301(a) of the FD&C Act, it was illegal to introduce these mislabeled medications into interstate commerce because they were manufactured at unregistered facilities. According to section 501(a)(2)(B) of the Act, Omni Lens is still solely accountable for CGMP compliance even with the use of CMOs, the FDA stressed. Because of this, on September 27, 2024, the company was put on Import Alert 66-40, which forbade the importing of its goods into the United States. Omni Lens is required to present a thorough rehabilitation plan that addresses procedural errors, QU problems, and upper management's backing for quality control. Neglecting to deal with these offenses

CASE STUDY2: Data fabrication / Falsified Chloroquine Tablets in Africa

Although there is little evidence to support it, chloroquine (CQ) and hydroxychloroquine (HCQ) received a lot of political and media attention in early 2020 as possible COVID-19 therapies. As a result of this unexpected interest, demand for these medications skyrocketed and soon exceeded supply. This raised the possibility that counterfeit medications would reach the market and raised the risk of shortages for their authorized purposes, including as the treatment of autoimmune disorders and malaria (CQ). There were reports of fake CQ tablets being sold in pharmacies and unofficial marketplaces in Cameroon and the Democratic Republic of the Congo (DR Congo). Ecumenical Pharmaceutical Network (EPN) local thin-layer chromatography (TLC) analysis of these counterfeit medications revealed no CQ. An international Medical Product Alert resulted from EPN's notification of the WHO about the problem, which was aided by the German Institute for Medical Mission (Difaem). Additional fabricated CQ samples were found during follow-up investigations in Cameroon and the Democratic Republic of the Congo. These samples were then forwarded to Germany for in-depth examination. The falsification was verified by comparing the phony tablets to real CQ samples using thin-layer chromatography testing. To confirm the findings, sophisticated techniques such as mass spectrometry and high-performance liquid chromatography were employed. These initiatives made clear how crucial it is to keep an eye on the quality of medications, particularly in times of medical emergency, in order to stop the spread of harmful fake medications. The risk of counterfeit medications has been brought to light by the COVID-19 pandemic, especially in low- and middle-income countries (LMICs), which struggle with issues like governance, poor quality assurance systems, and restricted access to medications. This problem is made worse by disruptions in global production and supply chains, particularly in key producing nations like China and India, which impact not only COVID-19 treatments but also a wide spectrum of necessary medications.

CONCLUSION

Because of insufficient supervision by its quality unit (QU) and inappropriate responsibility delegation to contract manufacturing organizations (CMOs), Omni Lens Pvt. Ltd. was unable to adhere to CGMP regulations. Mislabeled medications and unregistered manufacturing facilities are examples of infractions that resulted from the company's failure to ensure appropriate production practices. Because of these violations, the FDA banned the company's products from being imported into the US and placed it on Import Alert 66-40. Omni Lens must improve QU oversight, put in place a strong remediation strategy, and make sure that CGMP rules are followed in order to rectify



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these infractions. If these problems are not resolved right away, additional regulatory actions could be taken, such as denying approval for new drug applications.(10) In times of crisis such as the COVID-19 pandemic, low- and middle-income countries (LMICs) are particularly vulnerable to counterfeit medications, as demonstrated by the discovery of fake chloroquine (CQ) in Cameroon and the Democratic Republic of the Congo. Regulatory restrictions, resource shortages, and supply chain interruptions that increase these hazards must be addressed by fortifying drug quality monitoring systems and encouraging global cooperation.(11) Misconduct in regulatory filings can lead to serious repercussions for both the pharmaceutical industry and public health. Such practices may result in delays in the approval of effective treatments, the approval of hazardous products, a decline in public trust, heightened regulatory demands, and harm to the industry's reputation and a reduction in investor confidence. To reduce these risks, it is crucial to establish strong regulatory supervision, encourage ethical behavior in the industry, and cultivate a culture of transparency and accountability. The FDA's Form 483 observations, made during inspections, point out shortcomings in regulatory submissions. Such observations may result in heightened scrutiny and approval delays.

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**Table.1: The possible consequences of unreported conflicts of interest(6)**

S.NO	Interventions	The possible consequences of unreported conflicts of interest
1	Rosiglitazone	Rosiglitazone was linked to cardiovascular risk, according to a meta-analysis, and the safety of the medication was more likely to be supported by papers written by academics with conflicts of interest. Notably, conflicts of interest were not disclosed in 23% of these articles. For safety issues, rosiglitazone was taken off the market in a number of nations; however it is still accessible in the United States.
2	Alteplase	Among the concerns of emergency physicians was intracerebral bleeding. Seven panelists out of the eight who developed the rules had indirect financial relationships to the alteplase company, which could have created conflicts of interest. But only three of them revealed these conflicts. Following these disputes, the American Heart Foundation withdrew its claims that the intervention could save lives.
3	Risperidone	A leading researcher in pediatric clinical trials for risperidone, who also helped broaden the diagnostic criteria for childhood bipolar disorder, failed to disclose financial ties to the drug's manufacturer. After a congressional investigation, he was found guilty of violating university and federal conflict of interest regulations.
4	Calcium-channel antagonists	A survey study found that authors with financial conflicts of interest were more likely to give positive reviews on the safety of calcium channel antagonists. Sixty-three percent of respondents admitted to having such conflicts, yet only two out of the 70 articles from these authors included proper disclosures.
5	Measles, mumps, rubella (MMR) vaccine	A study linking the MMR vaccine to autism was withdrawn after it was revealed that an author had concealed his financial motivations for criticizing the vaccine. Despite this, the impact on vaccine decision-making remains significant, with over one in five people still believing that vaccines cause autism, even ten years later.
6	Neuraminidase inhibitors	During the 2009 H1N1 pandemic, academics with conflicts of interest often promoted neuraminidase inhibitors or exaggerated the pandemic's risk in newspaper articles.

Table.2 : Number of FDA issued form 483 in each year from 2020 to 2024(9)

Years	No of FDA issued form 483 in each year
2020	7
2021	8
2022	28
2023	29
2024	51

Table.3: Number of FDA issued warning letters in each year from 2020 to 2024(10)

Years	No of FDA issued the warning letters in each year
2020	639
2021	688
2022	688
2023	599
2024	433





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Table.4: Falsified samples of chloroquine tablets identified in Cameroon and the DR Congo(11)

Sample code	I	II	III	IV
Stated product name	Chloroquine phosphate tablets U.S.P	Chloroquine phosphate tablets U.S.P	Cloroquine [sic] 250 mg	Chloroquine phosphate tablets U.S.P
Stated strength	100 mg	100 mg	250 mg	100 mg
Stated manufacturer	Jiangsu Pharmaceutical Inc., China	Jiangsu Pharmaceutical Inc., China	Dawa Limited, Kenya	Jiangsu Pharmaceutical Inc., China
Batch number, mfg date, exp date	660, August 2018, August 2022	660, May 2017, May 2021	1605059, May 2019, April 2023	660, May 2019, April 2023
Found in	Limbe, Cameroon	Douala, Cameroon	Bukavu, DR Congo	Douala, Cameroon
Type of facility found in	Private pharmacy	Private pharmacy	Informal vendor	Private pharmacy
Date of discovery	April 3, 2020	March 31, 2020	April 4, 2020	April 4, 2020

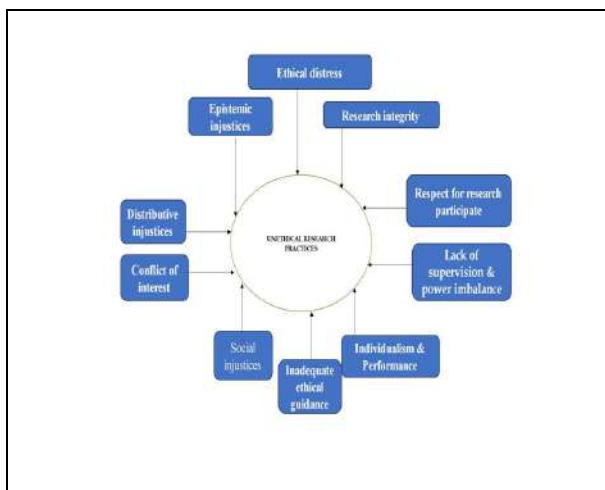


Figure.1: This figure shows the Unethical Research Practices (5)

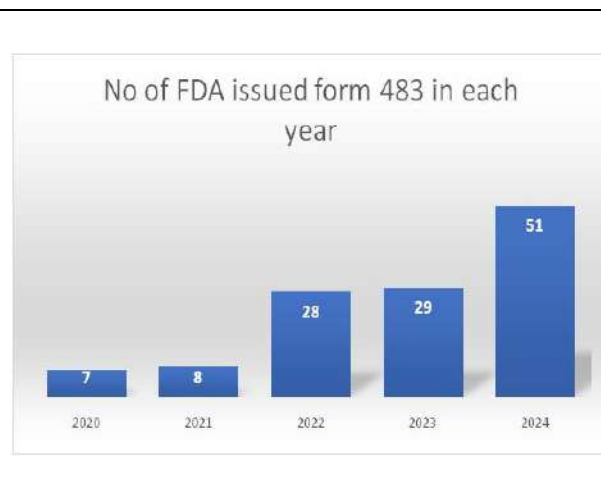


Figure.2: The graph visualizes the distribution of FDA-issued Form 483s across the years 2020 to 2024(9).

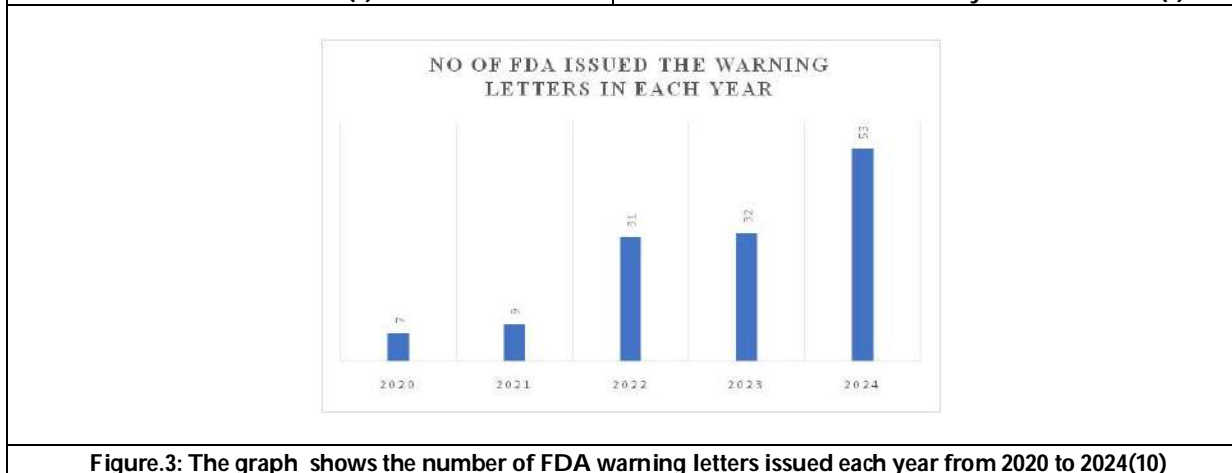


Figure.3: The graph shows the number of FDA warning letters issued each year from 2020 to 2024(10)





Synthesis, *In-silico* and *In-vitro* Antitubercular Activity Screening of Novel Pyrrolyl Thiazolidinone Derivatives

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ABSTRACT

A series of novel Pyrrolyl thiazolidinone derivatives were synthesized by the reaction between Pyrrolyl hydrazide in presence of substituted aldehyde, ethanol to obtain Pyrrolyl Schiff Base; Further Pyrrolyl Schiff Base in presence of thioglycolic acid and Benzene refluxed for 12hr to yield Pyrrolyl thiazolidinone derivatives(4a-c). Through FT-IR, ¹H NMR, ¹³C NMR and Mass Spectroscopy the synthesized compound were successfully confirmed, Pyrrolyl derivatives was thoroughly analyzed for their in-vitro antitubercular activity against Mycobacterium tuberculosis using H37Rv Strains by using Microplate Almar Blue Assay (MABA) method, Isoniazid and Rifampicin used as reference standard drugs. Among all the synthesized compound 4b shows good activity when compared to standard drugs. In-Silico, Molecular Docking Studies were carried out on newly synthesized compound Pyrrolyl thiazolidinone Derivatives(4a-c) using PyRx and Discovery studio software which shows the vital interaction and binding affinity.

Keywords: Pyrrole, IR, NMR, Molecular Docking, MABA Method.

INTRODUCTION

Tuberculosis (TB) is a chronic infectious disease caused by Mycobacterium tuberculosis it is the worlds second common cause of death from infectious disease after AIDS [1]. TB is a systemic disease with typical Pulmonary manifestation, which is transmitted from person to person by airborne bacteria [2]. Mycobacterium africanum,

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Mycobacterium bovis, *Mycobacterium microtic*, *Mycobacterium canetti*, *Mycobacterium tuberculosis* are five closely related *Mycobacteria* that produces the pandemic illness [3]. *Mycobacterium tuberculosis* has been the major causative agent of tuberculosis, a disease that affects the lungs, referred as pulmonary TB and some other part as well, referred as extrapulmonary TB [3,4]. Smoking, alcohol consumption, undernutrition are also the factors, which help in developing active tuberculosis. The situation has become more worst due to the development of XDR and MDR-TB strains. Tuberculosis, which is resistant to both isoniazid and rifampicin (most potent anti-TB drugs) is referred as MDR-TB. [5] Extensive drug-resistant tuberculosis (XDR-TB) is an another type of tuberculosis (TB) that is resistant to number of drugs like Isoniazid, Rifampicin, at least one fluoroquinolone, such as levofloxacin or moxifloxacin and at least one other Group A drug, such as bedaquiline or linezolid. First line and Second line drugs; The first line drugs that include Isoniazid, Rifampicin, Ethambutol and streptomycin. The first line drugs combines with greatest level of efficacy with acceptable degree of toxicity and also responsible for the adverse reaction. Second line drugs include Kanamycin, Cyclosterin, Ethionamide and Quinoline, Second line drugs shows potential nephrotoxicity. [6] According to the WHO; In 2022, around 2 billion people were infected with TB, In 2018, 1.6 million TB-related deaths and In 2017, 10 million new cases of TB were observed [3,7,8]. It has become crucial for TB control to create a quick diagnostic test that can differentiate between active TB and LTBI or active TB and non-active TB, as well as detect *M. tb* infection [9]. Tuberculosis is repeatedly diagnose using the GeneXpert assay, Sputum smear microscope and chest radiography. However, the culture method is considered as gold standard for detecting the causative agent of tuberculosis, *Mycobacterium tuberculosis*, but it is a time-consuming diagnosis with substantial contamination risks [10]. Pyrrole is a ubiquitous moiety. The characteristic reactions of Pyrrole are electrophilic substitution [11]. Pyrrole derivatives have been found to possess a wide spectrum of activities, of which anti-TB is one of the prominent one [12]. Pyrrole is present in many naturally occurring products like Vitamin B12, bile pigments like bilirubin and biliverdin, porphyrins of heme, chlorophyll, chlorins, bacteriochlorins and porphyrinogens. In 1929 E. Fischer first synthesized pyrrole containing moiety called Haemin [13]. In continuation with our research work on pyrrole derivatives [14,15,16,17], here we have developed novel Pyrrole derivatives with potent antitubercular activity.

Chemistry Apparatus

Round bottom flask, Condenser, Magnetic stirrer, Measuring cylinder, Beaker, Boiling chips, Petri dish, Glass Rod

Chemicals Required

Ethyl-4-aminobenzoate, 2,5-dimethoxy tetrahydrofuran, Glacial acetic acid, Hydrazine Hydrate, Ethanol, substituted aldehydes, thioglycolic acid, benzene, sodium bicarbonate, 2,3-Dimethoxybenzaldehyde, vanillin, anisaldehyde. Ethyl acetate : Chloroform in the ratio 7 : 3 & Ethyl acetate : petroleum ether in the ratio 6 : 4 for TLC

Software's- Chemdraw Professional 16.0, Chem 3D 16.0, PyRx, Discovery studio

Method

- **Step-1 Synthesis of ethyl 4-(1H-pyrrol-1-yl) benzoate (I):** Compound (I) was synthesized by refluxing a mixture of ethyl 4-aminobenzoate (0.05 mol) in glacial acetic acid (7.5ml) and 2,5-dimethoxy tetrahydrofuran (0.05 mol) at 150- 160 °C for 45 min. Then the reaction mixture was poured onto crushed ice further it was neutralized with saturated solution of sodium bicarbonate, the separated solid was filtered and recrystallized with ethanol.
- **Step-2 Synthesis of 4-(1H-pyrrol-1-yl) benzohydrazide (II):** Compound (II) was synthesized by refluxing a mixture of (I) (0.014 mol) with hydrazine hydrate (9.3ml) in absolute ethanol (9.3ml) for 3hr, further the reaction mixture was cooled. The obtained crystalline mass thus obtained was filtered and recrystallized from ethanol.
- **Step-3 Synthesis of Schiff base derivatives of pyrrole (III):** Compound (III) was synthesized by dissolving aromatic aldehyde (10mmol) in ethanol and was treated with a solution of benzoic acid hydrazide (10mmol) (10mmol) in ethanol (25ml), to this few drops of glacial acetic acid was added. The reaction mixture was then cooled down to room temperature and the precipitate was filtered, dried and recrystallized from ethanol to obtain the pure product.
- **Step-4 Synthesis of Pyrrolyl Thiozolidinone Derivative (IV):**





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To a solution of compound (III) add 0.9 ml of thioglycolic acid and 15 ml of benzene, the mixture was refluxed for 8-12hrs on water bath. The Upper organic layer was washed with sodium hydrogen carbonate solution and then with water, the Benzene was distilled off then the compound (VI) i.e Pyrrolyl thiazolidinone derivative was synthesized.

Biological Activity

For the newly synthesized compounds MIC value was determined against *M. tuberculosis* H37 RV strains using Microplate Alamar Blue Assay (MABA) using isoniazid as the standard drug. Compounds 3c, 3g and 3j showed significant antitubercular activity. Table-3 reveals antitubercular activity (MIC) data for all the synthesized compounds

In-Silico Studies

The synthesized compounds were evaluated using molecular docking study software such as chemdraw Professional, chem3D 16.0, PyRx and Discovery studio. Based on the literature review (Decaprenylphosphoryl-beta-D-ribose oxidase of organism *Mycobacterium tuberculosis* H37Rv strain) 6G83 strains was selected and downloaded from RCSB-Protein Data Bank (PDB). By using chemdraw and chem3D the ligand was prepared. Furthermore by using PyRx software the docking of protein and synthesized ligand molecule was performed, where the binding affinity of each synthesized compound was found and then the docked structure of protein-ligand complex was obtained. Visualization of Docked structure was done using Discovery Studio.

RESULTS AND DISCUSSION

Compound IV (Pyrrolyl thiazolidinone derivatives) was synthesized and melting point is as follows;

The Spectral Data of The Newly Synthesized Pyrrole Derivatives(4a-c)

- **FT-IR spectrum of 4a:** 3205-90(-NH stretching); 2918.74(-CH stretching); 1685.81(- C=O stretching); 1512.94(-C=C stretching); 1278.64(-C-N stretching)
¹H NMR (DMSO) 500MHz (δ ppm)(4a): 3.7-3.8(s 3H, -CH); 4.1(d 1H, Ar-CH); 6.0(s 1H, Ar-CH); 6.35-6.38(s 3H, Pyrrole); 6.8(s 1H, Pyrrole); 6.9(d 2H, Pyrrole); 7.0-7.8(d 5H, Ar-CH); 8.4(s 1H, OH)
- **FT-IR spectrum of 4b:** 3251.62(-NH stretching); 2920.17(-CH stretching); 1641.52(- C=O stretching); 1507.23(-C=C stretching); 1327.22(-CN stretching)
¹H NMR(CDCl₃) 500MHz (δ ppm) 4b: 2.0-2.3 (m 6H, CH); 3.9 (d, 1H, CH); 6.3 (s, 1H, Pyrrole); 7.1 (s 2H, Ar-CH); 7.2 (d, 2H, Pyrrole); 7.3 (t, 2H, Ar-CH); 7.5 (d, 2H, Ar-CH); 7.6 (d, 2H, Ar-CH); 9.9 (s, 1H, NH)
¹³C NMR(CDCl₃) 500MHz (δ ppm) 4b: 150.1(C24 of terminal benzene), 149.5(C24 of terminal benzene), 143.7(C6 of bridged benzene), 128.9-129.2(C9 of bridged benzene), 121.4(C1, C2 of Pyrrole), 118.9(C26 of terminal benzene), 111.1(C23 of terminal benzene), 110.4(C2, C3 of Pyrrole), 56.05(C30, C28 of aliphatic compounds)

Mass Spectral Data: Molecular Weight of the Compound 4b is 446 m/z

FT-IR spectrum of 4c: 3217.33(-NH stretching); 2918.74(-CH stretching); 1717.24(- C=O stretching); 1510.09(-C=C stretching); 1327.22(-CN stretching)

¹H NMR(CDCl₃) 500MHz (δ ppm) 4c: 0.8 (s, 2H, CH); 1.2 (s, 8H, CH)

3.7 (d, 2H, CH); 6.3 (s, 1H, Pyrrole); 7.0 (s, 1H); 7.2-7.4 (d, 2H, Ar-CH); 7.7 (d, 1H, Ar-CH) Newly Synthesized compounds(4a-c) were tested for antitubercular activity using MABA method against H37Rv strain. The compound 4b shows good anti-tubercular activity with MIC value of 62.5µg/mL are shown in the Table no-6.

Molecular docking study for newly synthesized derivatives(4a-c)

By doing literature study, the crystal structure of protein Decaprenylphosphoryl-beta-D-ribose oxidase)6G83 [18] was downloaded from Protein Data Base [PDB].



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In this research work, by the reaction between ethyl-4-aminobenzoate and 2,5-dimethoxy tetrahydrofuran in dried acetic acid the compound (1) was synthesized. The synthesized compound (1) was then reacted with hydrazine hydrate in absolute ethanol to yield the compound (2), the compound (2) in the presence of aromatic aldehyde and ethanol which was refluxed for 3hr yields the compound (3). Further the compound (3) was refluxed in the presence of thioglycolic acid and benzene for 12hrs to yield the compound (4a-c). The Physicochemical data of newly synthesized Pyrrolyl thiazolidinone derivatives (4a-c) given in table no-01 where the purity of the synthesized compound was confirmed and then the synthesized compound 4a-c subjected for spectral characterization data such as FT-IR, ¹H NMR, ¹³C NMR and mass spectroscopy. Antitubercular activity of the synthesized compound was carried out using *Mycobacterium tuberculosis* H37Rv strain using the Microplate Alamar Blue Assay (MABA) method. The compound 4b exhibit good antitubercular activity with MIC value of 62.5µg/ml, And the compound 4a and 4c shows moderate activity with the MIC value of 125µg/ml when compared with the standard drugs isoniazid and rifampicin. Further, In-silico studies were carried out using software Discovery studio and PyRx, which provides the data about the binding affinity for the docked ligand for the compound (4a-d) in which the compound 4b shows the good binding affinity of value of -6.2 against the target protein Decaprenylphosphoryl-beta-D-ribose oxidase (6G83), were as the compound 4a, 4c and 4d shows the value of -5.4, -5.1 and -5.8. The boiled egg model was also studied and observed to know the lipophilicity and hydrophilicity of the synthesized compounds, from which we got to know that all the synthesized compounds were hydrophilic in nature.

CONCLUSION

A novel series of Pyrrolyl thiazolidinone derivatives were synthesized by the reaction between Pyrrolyl Schiff Base in the Presence thioglycolic acid and benzene which was refluxed for 12hr to obtain Pyrrolyl thiazolidinone derivative (4a-c). The synthesized compound were characterized by the spectroscopic techniques such as FT-IR, ¹H NMR, ¹³C NMR and mass spectra. The synthesized compound further screened for the antitubercular activity against *Mycobacterium tuberculosis* H37Rv strain using the Microplate Alamar Blue Assay (MABA) method by using standard drug as rifampicin and isoniazid. The compound 4b shows good anti-tubercular activity with MIC value of 62.5µg/ml and the compound 4a and 4c shows the moderate activity with MIC value of 125µg/ml. Further, In-silico studies were carried out using software PyRx and Discovery studio, which provides the data about the binding affinity for the docked ligand, for the compound 4a-d in which the compound 4b shows the good binding affinity of value of -6.2 against the target molecule of Decaprenylphosphoryl-beta-D-ribose oxidase (6G83), were as the compound 4a, 4c and 4d shows the value of -5.4, -5.1 and -5.8. Through boiled egg model we can also conclude that all compounds are hydrophilic in nature. Hence, we conclude that this study will serve as a valuable guide for the further, design and synthesis of more effective pyrrole derivatives for the treatment of tuberculosis.

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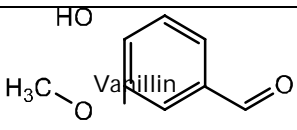
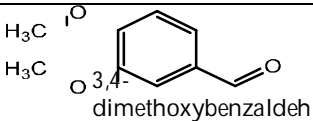




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Table 1. (Physicochemical data of compound III)

com p	R	Melting Point	Molecular Formula	Molecular weight	RF Value
4a		1800 C	C21H17N3O4 S	40 7	0.772
4b		1870 C	C22H19N3O4 S	42 1	0.80





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4c		1840 C	C ₂₁ H ₁₇ N ₃ O ₃ S	39 1	0.82
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Mobile phase: For compound 4a, 4b- Ethylacetate: Chloroform (7:3); for 4b- Ethylacetate : n-petroleumether(6:4)and
Detecting agent: Iodine Chamber.

Table 2. Screening of Anti-tubercular activity by MABA method for newly synthesized compounds

Compounds	MIC μ g/mL
4a	125 μ g/mL
4b	62.5 μ g/mL
4c	125 μ g/mL
Rifampicin	0.98 μ g/mL
Isoniazid	1.95 μ g/mL

Table 3. Binding Affinity of Docked Ligand

Compound	Binding Affinity	Mode	RMSD/Lb	RMSD/Ub
4a	-5.4	0	0.0	0.0
4b	-6.2	0	0.0	0.0
4c	-5.1	0	0.0	0.0

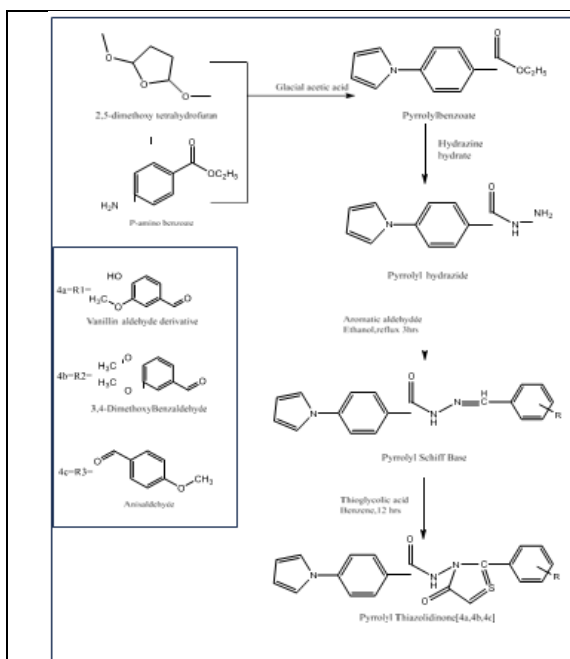


Figure 1: Synthesis Scheme of pyrrolyl thiazolidinone derivatives (4a-c)

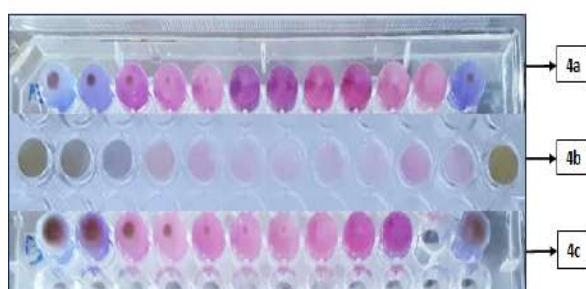


Figure 2: Anti-tubercular activity result of compound (4a-c)





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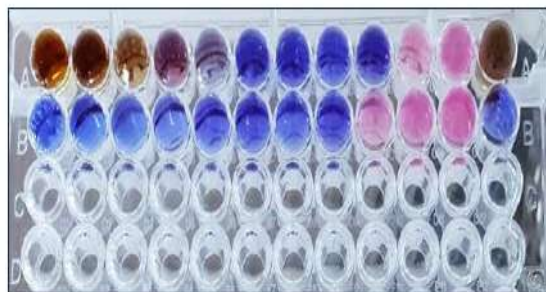


Figure 3: Compared with Standard [Rifampicin and Isoniazid] [fig;4]



Figure 4: Decaprenylphosphoryl-beta-D-ribose oxidase)6G83

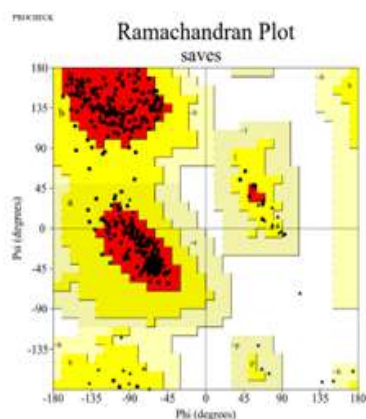


Figure 5: (3D & 2D) structure of compound 4a

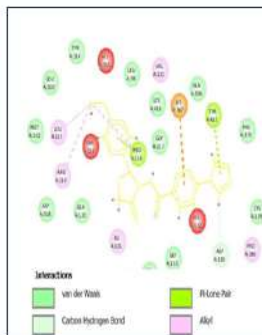
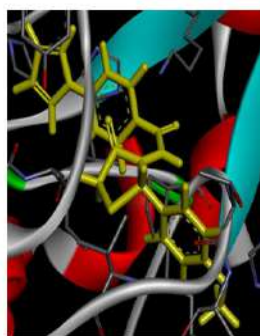
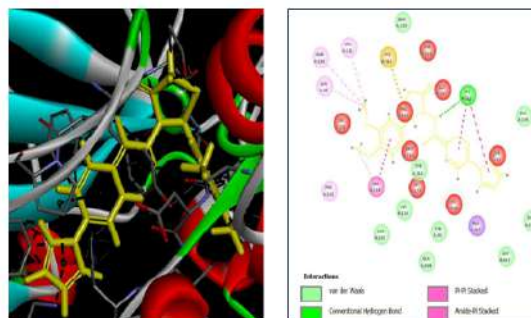


Figure 6: (3D & 2D) structure of compound 4b

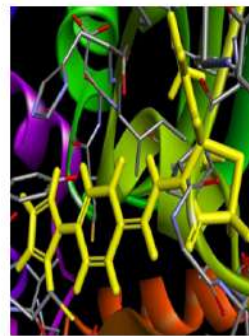


Figure 7: (3D & 2D) structure of compound 4c





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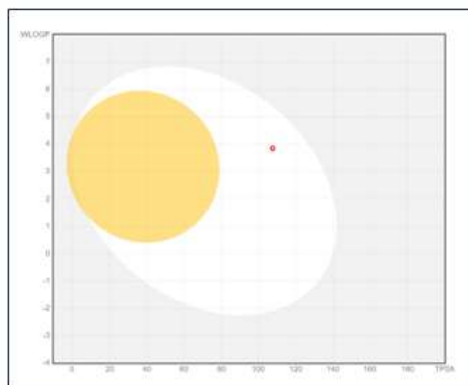


Figure 8: Boiled egg model(4a)

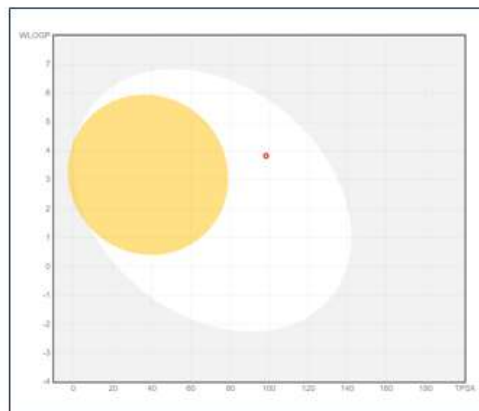


Figure 9: Boiled egg model(4b)

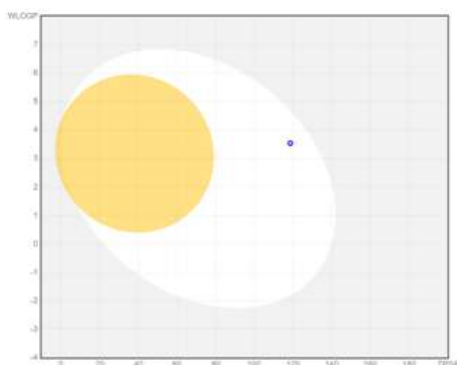


Figure 10: Boiled egg model(4c)





Formation, Essential Characterization and Biological Studies of Novel 2,4-Dichloro-6- [(4-Hydroxy-Phenylimino)- Methyl]- Phenol (Dcsap-L) and Ni(II), Zn(II), Mn(II), Co(II) Metal Complexes Derived from 3,5-Dichlorosalicylaldehyde with P-Aminophenol

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ABSTRACT

The increasing resistance of microbes to existing antibiotics underscores the urgent need for novel and effective antibacterial and antifungal agents. This study emphasizes on characterization, synthesis, and biological assessment of a novel ligand, DCSAP-L, and its corresponding "transition metal complexes. DCSAP-L was produced via 3,5-dichlorosalicylaldehyde with p-aminophenol condensation reaction, then coordination with transition metal chlorides of Ni(II), Zn(II), Mn(II), and Co(II) to form metal complexes. Synthesized compounds were thoroughly described utilizing analytical and methods to elucidate their structural and functional properties. Biological activity of ligand and its metal complexes was" assessed, revealing promising antimicrobial potential. These findings aid in synthesis of novel therapeutic compounds to address microbial resistance.

Keywords: 2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol, TGA/DTA, Spectral studies, Metal complexes, Biological activities.





INTRODUCTION

Schiff bases, first synthesized by Hugo Schiff in 1864 through Aldo-keto compounds condensation with primary or secondary amines, represent a versatile class of compounds with broad complexation abilities[1-3]. These compounds, characterized by the azomethine (CH=N) functional group, have become increasingly important as active and multifunctional ligands in various fields of chemistry[4-5]. Schiff bases and their metal complexes are notable for their significant roles in pharmaceutical and medicinal chemistry because of their diverse biological activities, encompassing antifungal, anti-inflammatory, antibacterial, and anticancer properties[6-7]. Hydroxyl-substituted Schiff bases, in particular, exhibit enhanced antimicrobial and anticancer activities. Furthermore, their complexes with transition metals namely Ni(II), Zn(II), Mn(II), & Co(II) find applications as catalysts in biological systems, analytical processes, polymer synthesis, dye production, and medicinal chemistry[8-14]. This study focuses on characterization, biological, and synthesis, examination of novel Schiff base, "2,4-dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol", and its metal complexes. Utilizing advanced analytical and spectral methods, compounds were thoroughly characterized, and their antimicrobial potential was assessed through *in vitro* studies, underscoring their effectiveness as bioactive agents.

Experimental Procedures

MATERIALS AND METHODS

"Chemicals, solvents, and glassware were procured from Merck and employed without additional purification. Analytical-grade reagents has been employed for preparation and recrystallization. Melting points of synthesized DCSAP-L and its metal complexes were ascertained utilizing Electro Thermal 9100 apparatus. "Elemental analysis (C, H, N)" was performed with EL(111) elemental analyzer", while mass spectra taken by "JEOL D-300-EI spectrometer". "UV-Visible spectra" was estimated with "Perkin Elmer Lambda 35 spectrophotometer" (250–800 nm). Magnetic properties were assessed using a Goy instrument. IR spectra determined with a "Perkin Elmer RX-1 spectrophotometer", and NMR spectra (¹H and ¹³C) being acquired using Bruker Avance II (400MHz) with d₆-DMSO. Thermal stability was analyzed via TGA and DTA using a Perkin Elmer STA6000 under an inert hydrogen atmosphere.

Synthesis of DCSAP-L

The method for the synthesis of "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol" has developed according to methods discussed in published articles[15-17]. An equimolar amount, (1:1) ratio, of "3,5-Dichlorosalicylaldehyde" (1.910 g) in pure ethanol and 4-aminophenol (0.965 ml) are mixed well (Scheme 1). The reaction mixture is allowed to stir well using magnetic stirrer for 1 hour and allowed sometime for slow evaporation of the alcoholic solution by maintaining an average thermal condition, to emerge a dark orange product. The obtained product, Schiff base, first washed in absolute ethanol solution, then filtered and dried at ambient atmosphere. Recrystallization of the dark orange color precipitate is done from hot absolute ethanol solution. Quantity of product is 79%.

Preparation of Metal Complexes

Schiff base's hot solution "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol" (0.005 mol) and transition metal salts of "Ni(II), Zn(II), Mn(II), Co(II)" (0.005 mol) in absolute ethanol solution (20 ml) are mixed well separately. The mixtures then, allowed to reflux on heating mantles for about 5-6 hours with aqua's condenser to reduce the temperature in an ice-cold environment. The different colored solid compounds were separated out by filtrating, washed with enough amount of ether and dried in an atmospheric air (Scheme 2).

Investigation of Antibacterial Activities

Various concentrations of "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol" and its corresponding metal complexes, Ni(II), Zn(II), Mn(II), Co(II), (100, 200, 500, & 1000 µg/ml) were kept together. Sterile Petri dishes with 20ml



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of nutrient agar medium are inoculated with 24-hcultures of *E. coli* and *S. aureus*". After that, these plates had been incubated for 24 hrs at 37°Celsius. Inhibition zones' diameter around samples was utilized to gauge antibacterial activity. For contrast, gentamicin was employed as a positive control.

Investigation of Antifungal Activities

Multiple concentration (100, 200, 500 and 1000 µg/ml) of the metal complexes from "Ni(II),Zn(II),Mn(II),Co(II) with ligand,2,4"-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol were kept together. *Aspergillus niger* strains were sown in Petri dishes having 20ml of potato dextrose agar medium, and dishes were then incubated for 72 hrs at 27°Celsius. By estimating inhibition zone diameter that developed around wells, antifungal activity has been measured. Application of amphotericin B served as positive control.

RESULTS AND DISCUSSION

FT-IR Spectra

The IR spectra studies on synthesized compounds provide valuable knowledge about the geometry and the functional groups. The ligand, 2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol coordinated with corresponding metal ions are identified by the infrared spectrum and their functional groups are recognized by the corresponding Frequencies. Some notable IR spectral bands and their peculiar nature of the prepared ligand, "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol and its metal complexes" are discussed as follows. The band that was seen between 3248.13 cm⁻¹ is because of ν(OH) stretching vibration[18]. But in the metal complexes, these bands showed a decrease in frequency, exhibiting a broad band in the range of 3248.13–3142.76 cm⁻¹. The stretching frequency of H₂O is observed 3331.32–3440.95 cm⁻¹ in metal complexes but absent in ligand. Around 1641.01–1620.81 cm⁻¹, the stretching frequency of azomethine ν (CH=N) is obtained. The vibrational frequencies observed in the band region reveals the formation of metal complex with ligand through metal-ligand bondage (Fig. 1). The band seen in region of 1280.73cm⁻¹ belongs to bending frequency of (Ar-O). bands observed at 538.72–502.04 cm⁻¹, 447.62–422.13 cm⁻¹ and 784.89–754.21 cm⁻¹ has been because of bending frequencies of (M-O),(M-N) &(M-Cl) correspondingly[19,20]. Those peaks are not present in the ligand 2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol. Bands obtained around the region of 3091.30–2919.80cm⁻¹ depict the C-H stretching of aromatic ring.

¹H & ¹³C Nuclear Magnetic Resonance Spectra

The integrity of "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol (DCSAP-L) and its Zn(II) metal complex" was analyzed after dissolution in DMSO-d₆. The obtained ¹H NMR spectra revealed modest downfield shift in Zn(II) complex signals in contrast to free DCSAP-L, indicating successful coordination with the metal ion. The proton and carbon NMR spectra of "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol (DCSAP-L) and its Zn(II) complex" provide valuable insights into their structural features. In ¹H NMR spectrum of ligand, hydroxyl protons (OH) appeared as distinct signals at 12.37 ppm and 9.47 ppm, while the imine proton (CH=N) was observed as a singlet at 8.61 ppm. Upon complexation with Zn(II), these signals exhibited an up field shift, indicating the retention of the metal-nitrogen bond in solution. Notably, although the complex contains two hydroxyl groups, only one OH signal was observed at 8.97 ppm, suggesting that one hydroxyl group was deprotonated and coordinated to metal ion. Additionally, aliphatic C-H protons were assigned to signals in the range of 2–3 ppm. Ligand's ¹³C NMR spectra displayed signals between 116.01 and 155.19 ppm, corresponding to aromatic and imine carbon atoms, consistent with reported literature values[21–24]. Aromatic carbons adjacent to the nitrogen atom exhibited downfield shifts, while the phenolic carbon (Ar-C-O) showed a distinct signal further downfield compared to other carbons. For the Zn(II) complex, the azomethine carbon (Ar-C=N) appeared at 167.70ppm, and phenolic carbon (Ar-C-O) was seen at 171.75ppm. Signals for the aromatic carbons of the ligand ranged from 116.52 to 161.99 ppm, reflecting the coordination environment in the metal complex. These findings confirm the successful ligand interaction with metal ion via both imine nitrogen and phenolic oxygen groups.



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Ultra Violet-Visible Spectra

The visible region's absorption peaks are explained by d-d transitions that take place at different energy levels and provide insights about complexes' electronic structure and geometry. At room temperature, "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol (DCSAP-L) and its transition metal complexes" were measured for UV-visible absorption spectra between 200-800nm. Geometry of metal complexes was ascertained employing these spectra along with magnetic data (Fig. 3). Structural features and coordination behavior of complexes were confirmed by analyzing electronic spectra of ligand and its metal complexes in DMSO solution [25–26].

Thermal Analysis

"Differential thermal analysis (DTA)" and "thermogravimetry (TG)" are two thermal analysis techniques that give information on thermal stability and decomposition behavior of materials. TG measures mass changes as temperature increases at a controlled rate, Temperature differential between sample (Ts) and reference (Tr) is assessed by DTA throughout predetermined temperature range. Resulting DTA curve highlights peaks corresponding to thermal events caused by processes such as desorption, absorption, and sublimation. The Zn(II) complex underwent three separate phases of thermal decomposition, as illustrated in the TG curve. An initial negligible weight loss below 125°C was attributed to adsorbed water. Dehydration of coordinated water molecules began at 130°C, with a significant mass loss observed at a DTG peak of 165°C[27]. Chloride ion decomposition occurred during second stage, which took place between 235°C and 240°Celsius, with a DTG peak near 365–370°C. In the final stage, the ligand, 2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol (DCSAP-L), decomposed between 370°C and 375°C, exhibiting DTG peak at 525°Celsius. The remaining residue mass loss was recorded, providing valuable insights into the complex's thermal behavior (Fig. 4).

Antimicrobial Activities

The antimicrobial activity of "2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol (DCSAP-L) and its metal complexes was" evaluated applying "well-diffusion method", following a standard procedure. Sterilized glassware was prepared using a hot air oven. The study assessed "antibacterial activity against *S. aureus* (Gram-positive) and *E. coli* (Gram-negative) along with antifungal activity against *A.niger*. Viable bacterial as well as fungal cells were evenly swabbed onto nutrient agar plates", subsequently treated with test samples at concentrations of 4, 15, and 30 mg/mL. Sterilized forceps were used to place the samples on the agar, and incubate plates for 48 hours at 37°Celsius. Antimicrobial efficacy was evaluated by measuring "inhibition zones" in millimeters following incubation. Findings indicated that against investigated microorganisms ligand and its metal complexes both demonstrated strong antimicrobial activity. Notably, metal complexes' antibacterial properties outperformed free ligand. This enhanced activity ascribed to coordination of Schiff base with transition metals, which likely increased complexes' biological potential.

CONCLUSION

Spectroscopic, analytical, and elemental investigations have been employed to fully describe the newly synthesized "Schiff base and its metal complexes. Findings reveal that metal complexes of 2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol exhibit significantly enhanced antimicrobial properties in comparison to free Schiff base ligand. Of all complexes" that were produced, Co(II) complex showed greatest antifungal and antibacterial activities, highlighting its potential as a promising antimicrobial agent. These findings highlight how crucial metal coordination is to enhancing Schiff base ligands' biological efficacy.

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Table.1: Elemental, Color, Molar conductance, and Magnetic susceptibility of DCSAP-Land Ni(II), Zn(II), Mn(II) and Co(II) metal complexes

Compound	Molecular Formula	Molecular Weight	Absorption Maxima (nm)	YIELD%	Calculated/ (Obtained)			Color	μ_{eff} (BM)	Molar Conductance	M. P. (°C)	Geometry
					C	H	N					
DCSAP-L	C ₁₃ H ₁₉ Cl ₂ N ₂ O ₂	281.21	305 350	80	55.34 (55.76)	3.22 (3.71)	4.96 (4.21)	Dark orange	-	-	140	-
Ni(II) Complex	C ₂₆ H ₂₀ Cl ₄ N ₆ O ₆	655.95	340 405	79	47.53 (48.12)	3.17 (4.01)	4.37 (4.71)	Greenish Brown	3.6	31	230	Oh
Zn(II) Complex	C ₁₃ H ₁₉ Cl ₃ ZnNO ₃	398.87	300 740	72	39.04 (40.21)	2.52 (3.01)	3.50 (4.01)	Red	Dia	114	175	Dis.Td
Mn(II) Complex	C ₂₆ H ₂₀ Cl ₄ MnN ₂ O ₆	652.32	425	71	47.81 (46.89)	3.09 (3.56)	4.29 (4.87)	Yellowish orange	5.9	25	205	Oh



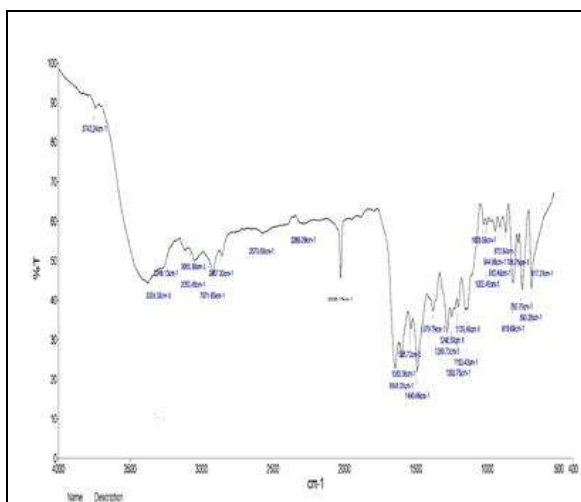


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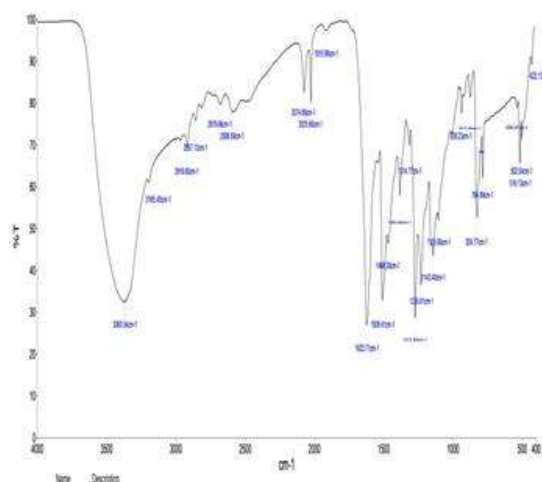
Co(II) Complex	C ₂₆ H ₂ oCl ₄ C oN ₂ O 6	582.59	610 675	75	47.52 (46.21)	3.07 (3.54)	4.26 (4.21)	Violet	4.6	28	>25 0	Oh
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Table.2:Antimicrobial activity data of DCSAP-Land Ni(II), Zn(II), Mn(II), Co(II) metal complexes

Compounds	Zone of inhibition in (mm) (µg/ml)											
	Bacteria								Fungi			
	<i>Staphylococcus aureus</i>				<i>Escherichia coli</i>				<i>Aspergillus niger</i>			
	1000	500	200	100	1000	500	200	100	1000	500	200	100
DCSAP-L	15.5	12.5	8.5	8	12	10	7.5	4.5	10.5	9.5	7.5	7.5
Ni(II) Complex	17	12.5	9.5	8	14	11	9	8	14.5	11.5	10	8.5
Zn(II) Complex	17	13	8.5	8	13.5	11.5	8.5	7	13.5	11	9.5	8
Mn(II) Complex	16	13	8	8	13.5	11	8.5	7.5	13	11	9	8
Co(II) Complex	22	15.5	12	11.5	15	11.5	10.5	10	17	12	10.5	9.5
Standard	18	22	14	Standard	18	22	14	Standard	18	22	15	Standard
Negative control	0	0	0	Negative control	0	0	0	Negative control	0	0	0	Negative control



DCSAP-L



DCSAP-Mn



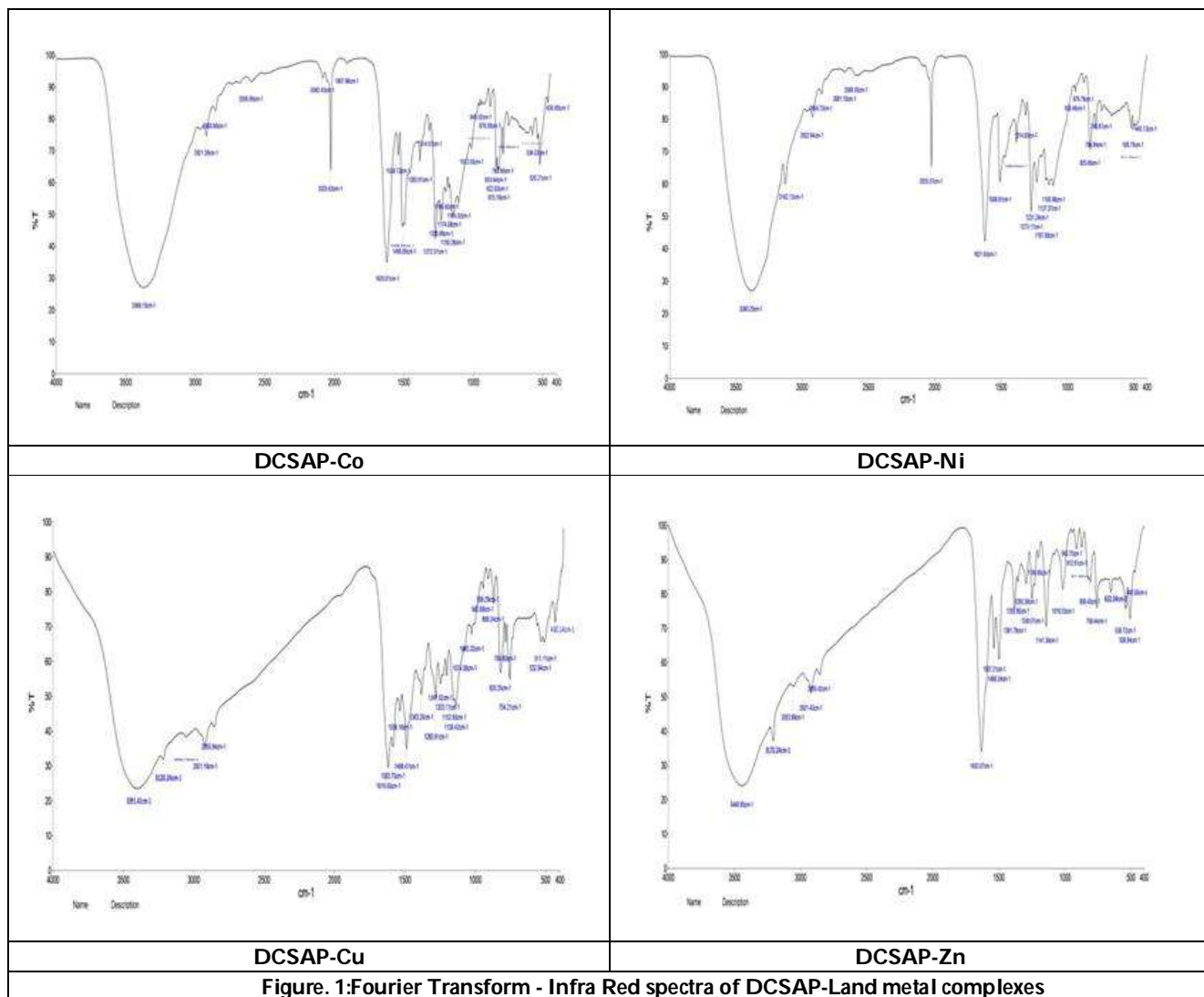
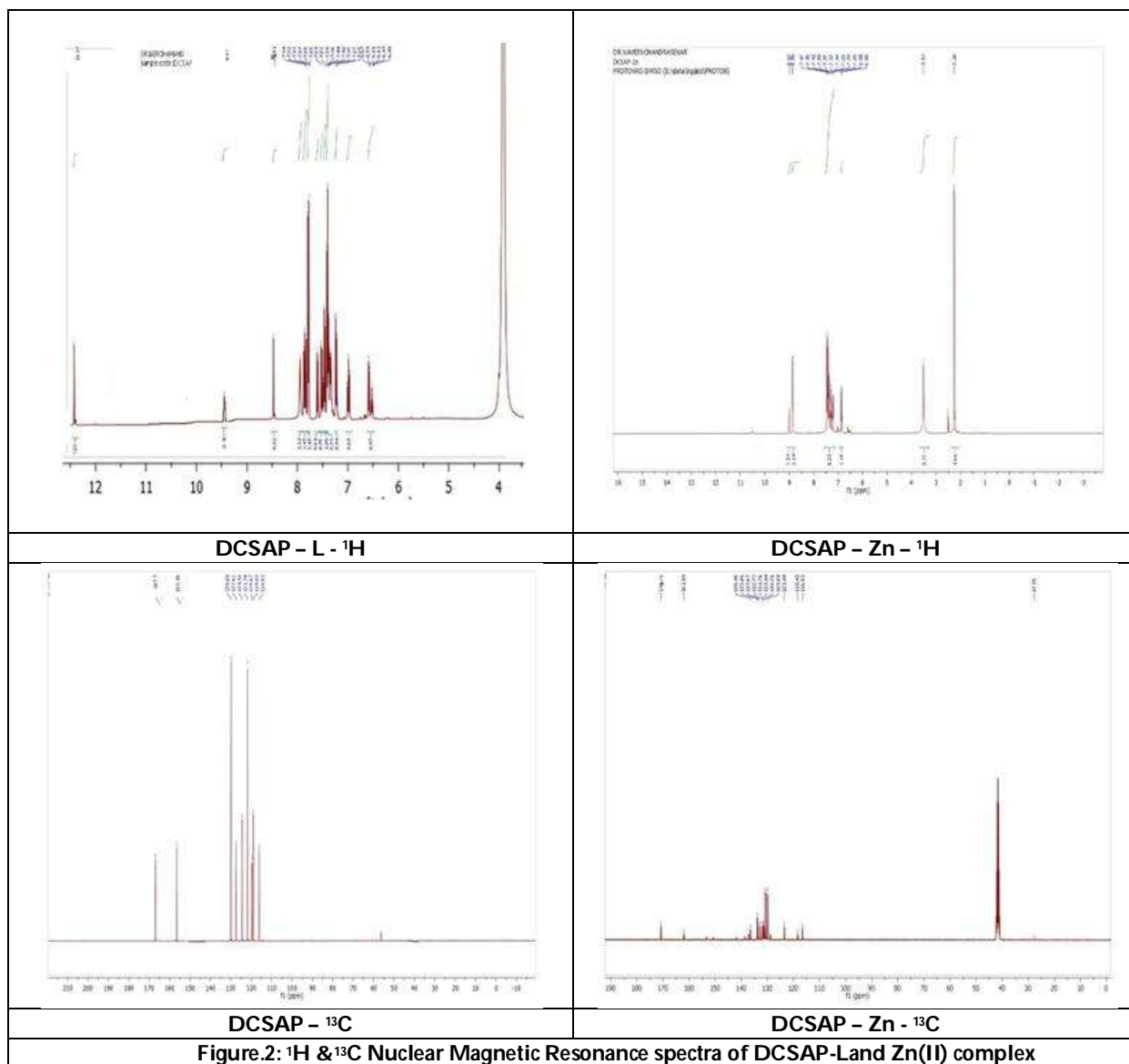
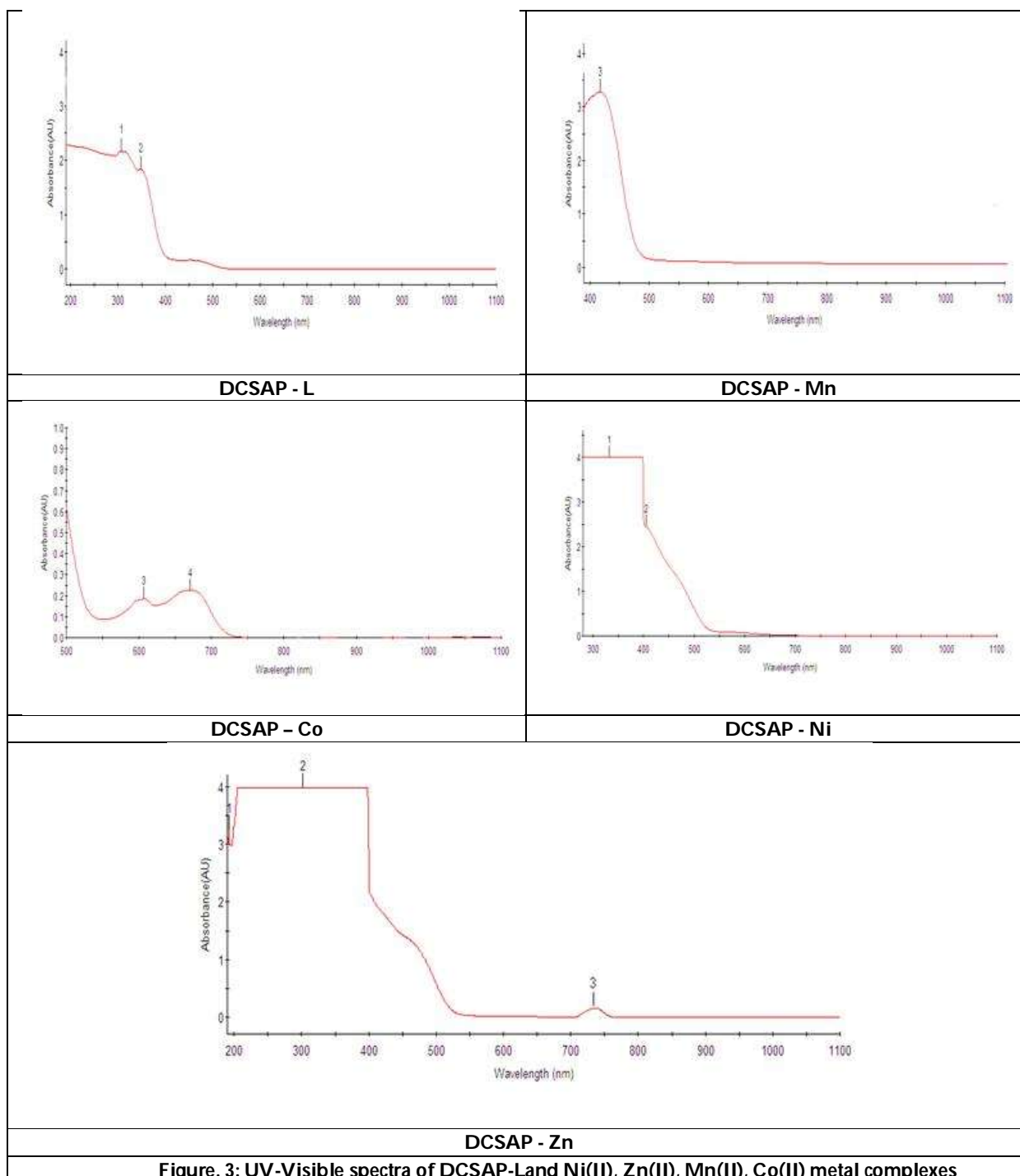
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Figure. 1:Fourier Transform - Infra Red spectra of DCSAP-Land metal complexes



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**Bijoy Joseph et al.,****Figure. 3: UV-Visible spectra of DCSAP-Land Ni(II), Zn(II), Mn(II), Co(II) metal complexes**

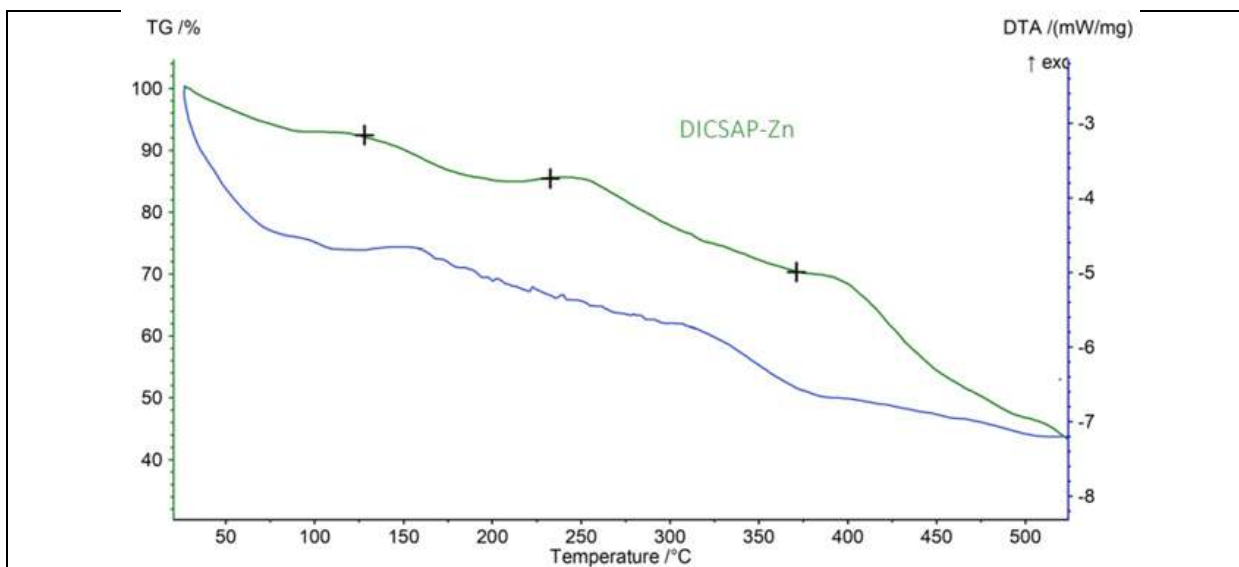
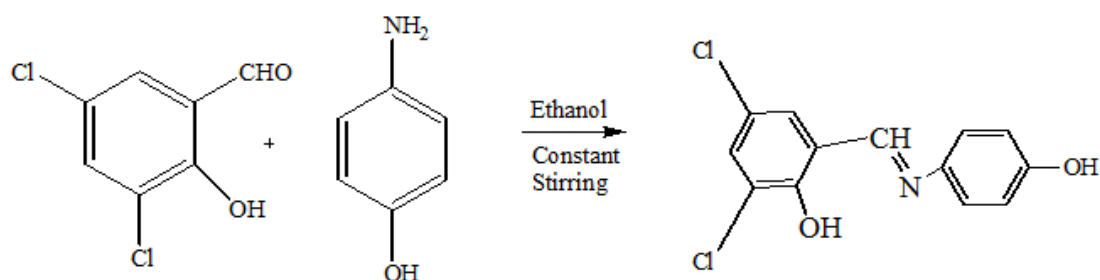
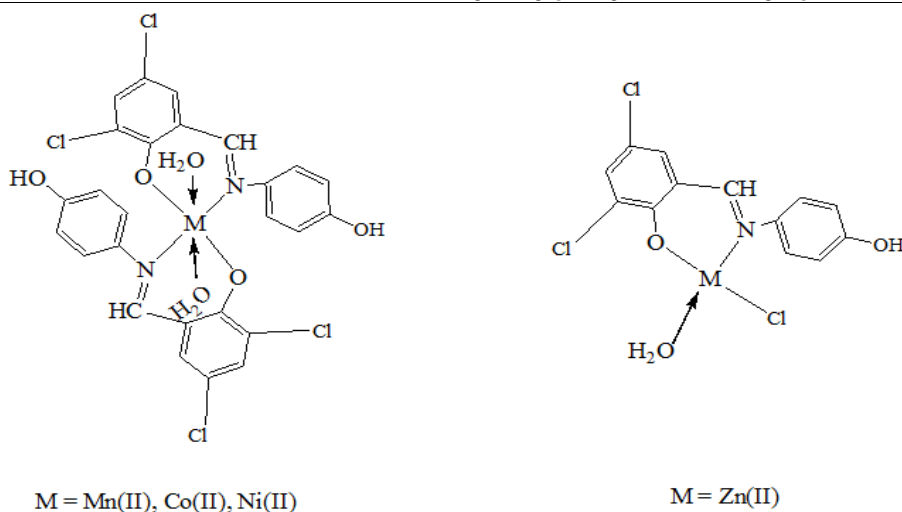
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Figure. 4: Thermo Gravimetric Spectrum of Zn(II) complex



Scheme.1: Formation of 2,4-Dichloro-6-[(4-hydroxy-phenylimino)-methyl]-phenol



Scheme.2: Structures of Mn(II), Ni(II), Co(II), Zn(II) Complexes





Optimal Control Measure in HMPV Virus in Infected Predator using Harvesting Effort

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ABSTRACT

This study investigates the application of optimal control strategies in managing the spread of the Human Metapneumovirus (HMPV) within a predator population. We extend a classic Lotka-Volterra prey-predator model to include disease dynamics and harvesting effort using a Holling Type II functional response. The system is divided into susceptible prey, infected prey, and predator populations, incorporating a force of infection and a harvesting term to account for predator exploitation. An optimal control framework is proposed, minimizing the cost of control interventions and maximizing the economic benefits from predator harvesting while ensuring population stability and disease mitigation. Stability analysis and numerical simulations are performed to explore the equilibria, disease persistence, and the impact of control measures on the system.

Keywords: Optimal control, Lotka-Volterra model, eco-epidemiology, HMPV virus, Holling Type II, harvesting effort, predator-prey dynamics, disease transmission, stability analysis, bioeconomic modeling.

MSC (Mathematics Subject Classification) Codes:

- **92D30:** Epidemiology
- **49K15:** Problems involving ordinary differential equations





- **93C15:** Control/optimal control of systems governed by ODEs
- **34D20:** Stability of solutions to ODEs
- **91B76:** Environmental economics (harvesting, pollution, etc.)

INTRODUCTION

In recent years, the spread of infectious diseases among animal populations has gained significant attention due to its impact on ecosystem dynamics and potential economic consequences. One such disease is the Human Metapneumovirus (HMPV), which affects various predator species, leading to changes in their population dynamics and disrupting the balance of prey-predator systems. Understanding and controlling the spread of such diseases within ecological frameworks is essential for maintaining biodiversity and ensuring sustainable resource exploitation. This paper focuses on an eco-epidemiological model that incorporates the dynamics of susceptible prey, infected prey, and predators in a prey-predator system. The model is an extension of the Lotka-Volterra equations with a Holling Type II functional response, which accounts for predator-prey interactions. Additionally, the model includes a harvesting effort aimed at exploiting the predator population while controlling the spread of HMPV.

The control of HMPV in infected predators presents a bioeconomic challenge: balancing the cost of interventions (e.g., reducing infection or limiting harvesting pressure) with the potential economic benefits of harvesting predators. To address this, we employ an optimal control framework to determine strategies that minimize the combined cost of disease spread and harvesting while maximizing economic gains.

This work investigates the following key objectives

1. To develop a mathematical model of the susceptible-infected prey-predator system with harvesting effort.
2. To apply optimal control theory for reducing HMPV transmission within the predator population.
3. To analyze the system's stability and equilibria under various control measures.
4. To evaluate the bioeconomic trade-offs between harvesting predators and controlling the disease.

This study contributes to the growing field of eco-epidemiology, providing insights into managing disease dynamics in predator populations while ensuring sustainable harvesting practices. Human metapneumovirus (HMPV) is a respiratory virus that can cause symptoms similar to those of the common cold or flu. It often affects children, older adults, and individuals with weakened immune systems. Common symptoms include Cough (often dry), Fever, Runny nose (rhinorrhoea), Sore throat, Wheezing, Shortness of breath, Fatigue, Headache, Muscle aches, Congestion (nasal), Ear infections (in some cases). Preventing infection involves adopting good hygiene practices and reducing exposure to the virus. Wash your hands frequently with soap and water for at least 20 seconds, especially after being in public places or touching shared surfaces. Keep your distance from people showing symptoms of respiratory illness, such as coughing, sneezing, or fever. Cover your mouth and nose with a tissue or your elbow when coughing or sneezing. Dispose of used tissues immediately. Wear a mask if you're sick to prevent spreading the virus to others.

Mathematical Model Assumption

When constructing a mathematical model for the spread or dynamics of the human metapneumovirus (HMPV), certain assumptions are typically made to simplify and represent the real-world system mathematically. These assumptions depend on the specific focus of the model, such as epidemiological dynamics, within-host virus dynamics, or population-level interactions. Here are common assumptions for an HMPV virus model.

$$\begin{aligned}\frac{dl}{dt} &= al - gml - aln - \frac{dln}{1+cl} - Hl \\ \frac{dm}{dt} &= gml + aln - \frac{bmn}{1+am} - qm - rm - Hm \\ \frac{dn}{dt} &= \frac{dln}{1+cl} + \frac{bmn}{1+am} - sn - \frac{fn}{n+u} - Hn\end{aligned}$$

Where,

l: Prey

m: Susceptible Predator





n : Infected Predator

a : Intrinsic growth rate of Prey species

g : Interference coefficient of susceptible, Infected Prey

α : Infection transmission rate from infected to susceptible predator

d : Capture rate of prey by predator

Hl : reduction due to harvesting in prey

Hm : Harvesting of susceptible predator

Hn : Harvesting of Infected predator

b : force of infection between infected prey and predator

D : conversion efficiency of infected predator.

q : Constant rate of recovery from the disease is possible due for instance to its immune System.

r : rate of natural death for all prey

s : natural death of predator

$\frac{fn}{n+u}$: Harvesting effort for Holling Type II function predator species where f is harvesting rate and m is the half saturation constant.

Positiveness and Boundedness of Theorem

In this phase, we seek to establish the requirements for obtaining both a positive and bounded solution of the system.

$$\frac{dl}{dt} = al - gml - \alpha ln - \frac{dln}{1+cl} - Hl$$

$$\frac{dl}{l} = [al - gml - \alpha ln - \frac{dln}{1+cl} - Hl]dt$$

$$\frac{dl}{l} = \lambda(l, m, n)dt$$

$$\text{Where } \lambda(l, m, n) = [al - gml - \alpha ln - \frac{dln}{1+cl} - Hl]$$

By integrating the area $[0, t]$, we obtain

$$l(t) = l(0) \exp \int \lambda(l, m, n)dt > 0 \forall \text{ as } l(0) \geq 0$$

Identically for Second set of equation

$$m(t) = m(0) \exp \int \alpha(l, m, n)dt > 0 \forall \text{ as } m(0) \geq 0$$

Identically for third set of equation

$$n(t) = n(0) \exp \int \beta(l, m, n)dt > 0 \forall \text{ as } n(0) \geq 0$$

As a result, it is possible to conclude that system solutions are consistently positive.

Proposition 1

In the domain $R_+^3 = \{l(t), m(t), n(t) \in R^3 : l \geq 0, m \geq 0, n \geq 0\}$ for all solution of system are bounded.

Proof:

We choose $K = l, m, n$ then differentiate with respect to t , we obtain

$$\frac{dk(t)}{dt} = \frac{dl(t)}{dt} + \frac{dm(t)}{dt} + \frac{dn(t)}{dt}$$

If we removing the interaction of the supplied system

$$\frac{dK(t)}{dt} + \psi K = (a-h)l + (-q-r)m + (-s-h)n - \frac{fn}{n+u} + \psi l + \psi m + \psi n$$

Where ψ is a positive constant for

$$(a-h+\psi) \geq 0, (-q-r+\psi) \geq 0, (-s-h+\psi) \geq 0 \text{ given } \epsilon > 0$$

There exists $t \geq t_0$

$$\frac{dK(t)}{dt} + \psi K = \left(\frac{a+\psi}{h}\right) + (-q-r+\psi) + \left(-s-H - \frac{fn}{n+u}\right)$$

$$= \chi + \epsilon$$



**Lemma 1**

Let ϕ be an absolutely continuous function satisfies the differential inequality.

$$\frac{d\phi(t)}{dt} + \gamma_1 \phi(t) \leq \gamma_2, t \geq 0 \text{ where } (\gamma_1, \gamma_2) \in \mathbb{R}_+^3, \gamma_1 \neq 0 \text{ then } \forall t \geq T \geq 0,$$

$$\phi(t) \geq \frac{\gamma_2}{\gamma_1} - \left(\frac{\gamma_2}{\gamma_1} \phi(T)\right) e^{-\gamma_1(t-T)}$$

From above lemma we obtain $0 \leq k(t) \leq k(t_0)e^{-\psi(t-t_0)} + \left(\frac{\chi+\epsilon}{\psi}\right)(1 - e^{-\psi(t-t_0)})$

Letting $t \rightarrow \infty$, then letting $\epsilon \rightarrow 0$, $\lim_{t \rightarrow \infty} \sup K(t) \leq \frac{\chi}{\psi}$

All solution of the system is bounded.

Equilibrium points

The system's equilibrium points are required to investigate the local stability of the prey-predator paradigm. We will discuss the important points' stability qualities. The system of equations under consideration has the following equilibrium points:

- 1) The trivial equilibrium points are $\{l=0, m=0, n=0\}$
- 2) Susceptible and Infected predator free equilibrium point $\{l=\frac{H}{a}, m=0, n=0\}$
- 3) Prey and Infected Predator free equilibrium point $\{l=0, m=\frac{-q+r}{H}, n=0\}$
- 4) Prey and susceptible predator free equilibrium point $\{l=0, m=0, n=\frac{f}{(-s-H)}\}$
- 5) Infected Predator free equilibrium point $\{l=\frac{H}{a}, m=\frac{r}{a}, n=0\}$
- 6) The non-trivial equilibrium points are $\{l=l^*, m=m^*, n=n^*\}$

$$\text{Where, } l^* = \frac{H}{a}, m^* = \frac{-q+r}{H}, n^* = \frac{(s+f+H)(1+c(\frac{H}{a}))}{d(\frac{H}{a})}$$

The Jacobian matrix of the system (1) at equilibrium points (l, m, n) is given by

$$J = \begin{bmatrix} a - gm - an - \frac{dcn}{(1+cl)^2} - H & -gl & -al - \frac{dl}{1+cl} \\ gm + an & gl - \frac{bn}{1+am} - \frac{bamn}{(1+am)^2} - q - r - H & al - \frac{bm}{1+am} \\ \frac{dn}{1+cl} - \frac{dcn^2}{(1+cl)^2} & \frac{bn}{1+am} - \frac{bamn}{(1+am)^2} & \frac{dl}{1+cl} + \frac{bm}{1+am} - s - \frac{f}{n+u} + \frac{fn}{(n+u)^2} - H \end{bmatrix}$$

Stability analysis**Theorem 2**

The dynamic system of equation is stable at equilibrium point $\{l=0, m=0, n=0\}$ provided that $\lambda_1 < 0$, $\lambda_2 < 0$ & $\lambda_3 < 0$ with the condition $H < a$, $H < q + r$, $H < S + \frac{f}{u}$.

Proof

The Jacobian matrix is

$$J_1 = \begin{bmatrix} a - H & 0 & 0 \\ 0 & -q - r - H & 0 \\ 0 & 0 & -S - \frac{f}{u} - H \end{bmatrix}$$

The eigenvalues are $\lambda_1 = a - H$, $\lambda_2 = -q - r - H$, $\lambda_3 = -S - \frac{f}{u} - H$. Hence the equilibrium point is stable with the condition $H < a$, $H < q + r$, $H < S + \frac{f}{u}$.





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Theorem 3

The dynamic system of equation is stable at equilibrium point $\{l=\frac{H}{a}, m=0, n=0\}$.

Proof:

The Jacobian matrix is

$$J_2 = \begin{bmatrix} a-H & -g\left(\frac{H}{a}\right) & -\alpha\left(\frac{H}{a}\right) - \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} \\ 0 & g\left(\frac{H}{a}\right) - q - r - H & \alpha\left(\frac{H}{a}\right) \\ 0 & 0 & \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} - S - \frac{f}{u} - H \end{bmatrix}$$

The eigen values are $\lambda_1 = a-H, \lambda_2 = g\left(\frac{H}{a}\right) - q - r - H, \lambda_3 = \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} - S - \frac{f}{u} - H$. Hence the equilibrium point is stable.

Theorem 4

The dynamic system of equation is stable at equilibrium point $\{l=0, m=\frac{-q+r}{H}, n=0\}$.

Proof:

The Jacobian matrix is

$$J_3 = \begin{bmatrix} a - g\left(\frac{-q+r}{H}\right) - H & 0 & 0 \\ g\left(\frac{-q+r}{H}\right) & -q - r - H & \frac{b\left(\frac{-q+r}{H}\right)}{1+a\left(\frac{-q+r}{H}\right)} \\ 0 & 0 & \frac{b\left(\frac{-q+r}{H}\right)}{1+a\left(\frac{-q+r}{H}\right)} - S - \frac{f}{u} - H \end{bmatrix}$$

The eigenvalues are $\lambda_1 = a - g\left(\frac{-q+r}{H}\right) - H, \lambda_2 = -q - r - H, \lambda_3 = \frac{b\left(\frac{-q+r}{H}\right)}{1+a\left(\frac{-q+r}{H}\right)} - S - \frac{f}{u} - H$. Hence the equilibrium point is stable.

Theorem 5

The dynamic system of equation is stable at equilibrium point $\{l=0, m=0, n=\frac{f}{(-s-H)}\}$.

Proof:

The Jacobian matrix is

$$J_4 = \begin{bmatrix} a - \alpha\left(\frac{f}{(-s-H)}\right) - dc\left(\frac{f}{(-s-H)}\right) - H & 0 & 0 \\ \alpha\left(\frac{f}{(-s-H)}\right) & b\left(\frac{f}{(-s-H)}\right) - q - r - H & 0 \\ d\left(\frac{f}{(-s-H)}\right) - d\left(\frac{f}{(-s-H)}\right)^2 & b\left(\frac{f}{(-s-H)}\right) & -S - \frac{f}{\left(\frac{f}{(-s-H)}\right)+u} + \frac{f\left(\frac{f}{(-s-H)}\right)}{\left(\left(\frac{f}{(-s-H)}\right)+u\right)^2} - H \end{bmatrix}$$

The eigenvalues are $\lambda_1 = a - \alpha\left(\frac{f}{(-s-H)}\right) - dc\left(\frac{f}{(-s-H)}\right) - H, \lambda_2 = b\left(\frac{f}{(-s-H)}\right) - q - r - H, \lambda_3 = -S - \frac{f}{\left(\frac{f}{(-s-H)}\right)+u} + \frac{f\left(\frac{f}{(-s-H)}\right)}{\left(\left(\frac{f}{(-s-H)}\right)+u\right)^2} - H$. Hence the equilibrium point is stable.

Theorem 6

The dynamic system of equation is stable at equilibrium point $\{l=\frac{H}{a}, m=\frac{r}{a}, n=0\}$.

Proof:

The Jacobian matrix is





$$J_5 = \begin{bmatrix} a - g\left(\frac{r}{a}\right) - H & -g\left(\frac{H}{a}\right) & -\alpha\left(\frac{H}{a}\right) - \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} \\ g\left(\frac{r}{a}\right) & g\left(\frac{H}{a}\right) - q - r - H & \alpha\left(\frac{H}{a}\right) - \frac{b\left(\frac{r}{a}\right)}{1+r} \\ 0 & 0 & \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} + \frac{b\left(\frac{r}{a}\right)}{1+r} - S - \frac{f}{u} + -H \end{bmatrix}$$

The eigenvalues are $\lambda_1 = a - g\left(\frac{r}{a}\right) - H$, $\lambda_2 = g\left(\frac{H}{a}\right) - q - r - H$, $\lambda_3 = \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} + \frac{b\left(\frac{r}{a}\right)}{1+r} - S - \frac{f}{u} + -H$. Hence the equilibrium point is stable.

Theorem 7

The dynamic system of equation is stable at equilibrium point $\{l = l^*, m = m^*, n = n^*\}$

Were,

$$l^* = \frac{H}{a}, m^* = \frac{-q+r}{H}, n^* = \frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}$$

Proof:

The Jacobian matrix is

$$J_6 = \begin{bmatrix} a_{11} & -g\left(\frac{H}{a}\right) & -\alpha\left(\frac{H}{a}\right) - \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} \\ g\left(\frac{-q+r}{H}\right) + \alpha\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right) & a_{22} & \alpha\left(\frac{H}{a}\right) - \frac{b\left(\frac{-q+r}{H}\right)}{1+a\left(\frac{-q+r}{H}\right)} \\ d\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right) - \frac{dc\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)^2}{\left(1+c\left(\frac{H}{a}\right)\right)^2} & a_{32} & a_{33} \end{bmatrix}$$

Were,

$$a_{11} = a - g\left(\frac{-q+r}{H}\right) - \alpha\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right) - \frac{dc\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{\left(1+c\left(\frac{H}{a}\right)\right)^2} - H$$

$$a_{22} = g\left(\frac{H}{a}\right) - \frac{b\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{1+a\left(\frac{-q+r}{H}\right)} - \frac{ba\left(\frac{-q+r}{H}\right)\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{\left(1+a\left(\frac{-q+r}{H}\right)\right)^2} - q - r - H$$

$$a_{32} = \frac{b\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{1+a\left(\frac{-q+r}{H}\right)} - \frac{ba\left(\frac{-q+r}{H}\right)\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{\left(1+a\left(\frac{-q+r}{H}\right)\right)^2}$$

$$a_{33} = \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} + \frac{b\left(\frac{-q+r}{H}\right)}{1+a\left(\frac{-q+r}{H}\right)} - S - \frac{f}{\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)} + u\right)} + \frac{f\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)} + u\right)^2} - H$$





The eigenvalues are $\lambda_1 = a - g\left(\frac{-q+r}{H}\right) - \alpha\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right) - \frac{dc\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{(1+c\left(\frac{H}{a}\right))^2} - H$, $\lambda_2 = g\left(\frac{H}{a}\right) - \frac{b\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{1+a\left(\frac{-q+r}{H}\right)} - \frac{ba\left(\frac{-q+r}{H}\right)\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{(1+a\left(\frac{-q+r}{H}\right))^2} - q - r - H$

, $\lambda_3 = \frac{d\left(\frac{H}{a}\right)}{1+c\left(\frac{H}{a}\right)} + \frac{b\left(\frac{-q+r}{H}\right)}{1+a\left(\frac{-q+r}{H}\right)} - S - \frac{f}{\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)} + u\right)} + \frac{f\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)}\right)}{\left(\frac{(s+f+H)\left(1+c\left(\frac{H}{a}\right)\right)}{d\left(\frac{H}{a}\right)} + u\right)^2} - H$. Hence the equilibrium point is stable.

The characteristic equation is $\Delta(\lambda) = \lambda^3 + F_1\lambda^2 + F_2\lambda + F_3$

Where $F_1 = -(a_{11} + a_{22} + a_{33}) = 3I(a_{11} + a_{22} + a_{33})$

$$F_2 = a_{11}a_{22} + a_{11}a_{33} - a_{12}a_{21} - a_{13}a_{31} + a_{22}a_{33} - a_{23}a_{32} \\ = 3I^2 - (2a_{11} + 2a_{22} + 2a_{33})I + a_{11}a_{22} + a_{11}a_{33} - a_{13}a_{31} + a_{22}a_{33} - a_{23}a_{32} - a_{12}a_{21}$$

$$F_3 = a_{11}a_{32}a_{23} - a_{11}a_{22}a_{33} + a_{12}a_{21}a_{33} - a_{12}a_{23}a_{31} - a_{13}a_{21}a_{32} + a_{13}a_{22}a_{31} \\ = I^3 - (a_{11} + a_{22} + a_{33})I^2 + (a_{11}a_{33} + a_{22}a_{33} + a_{11}a_{22} - a_{23}a_{32} - a_{13}a_{31} - a_{12}a_{21})I - (a_{11}a_{22}a_{33} + a_{11}a_{32}a_{23} + a_{13}a_{22}a_{31} + a_{12}a_{21}a_{33} - a_{12}a_{23}a_{31} - a_{13}a_{21}a_{32})$$

Numerical solution

- First, we assume the parameter of the system as (a, b, c, d, g, f, H, I, m, n, q, r, s) is (2.345, 1.09, 1.35, 0.32, 0.545, 0.005, 1.324, 1.543, 0.231, 2.06, 2.09, 1.17, 1.342) at the population (I, m, n) = (5.46, 5.65, 5.78).
- If assume the parameter of the system pointed above (1). Then initial condition Satisfied (I, m, n) = (0, 1.9, 0) the Susceptible predator population (figure 1).
- If assume the parameter of the system pointed above (1). Then initial condition Satisfied (I, m, n) = (0, 0, 3.5) the Infected predator population (figure 2).
- If assume the parameter of the system pointed above (1). Then initial condition Satisfied (I, m, n) = (0.25, 0, 0) the prey population (figure 3).
- If assume the parameter of the system pointed above (1). Then initial condition Satisfied (I, m, n) = ((0, 1.54, 1.78) (0.2, 1.2, 2.3)) the interconnect between Susceptible and infected predator population (figure 4).
- If assume the parameter of the system pointed above (1). Then initial condition Satisfied (I, m, n) = ((1.43, 1.54, 1.78) (0.8, 2.12, 2.3) (1.45, 0.65, 1.9) the interconnect between prey-predator population (figure 5).

CONCLUSION

This study explores the implementation of optimal control strategies in the management of predator populations infected with the HMPV virus, considering harvesting as a control mechanism. Through mathematical modeling and simulations, we identified optimal harvesting efforts that minimize the prevalence of the HMPV virus while maintaining ecological and economic sustainability. Our results highlight the delicate balance between maintaining predator population health, ensuring ecosystem stability, and optimizing harvesting yields. Furthermore, the application of Pontryagin's Maximum Principle allowed us to establish conditions under which harvesting reduces infection rates without compromising predator survival. These insights provide a valuable framework for resource managers and policymakers aiming to control zoonotic diseases in wildlife populations while maximizing benefits from ecosystem services.

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Conflict of Interest

The authors declare no conflicts of interest in the publication of this research. All data, methodologies, and conclusions presented in this study have been formulated without any bias or influence from external organizations or individuals.

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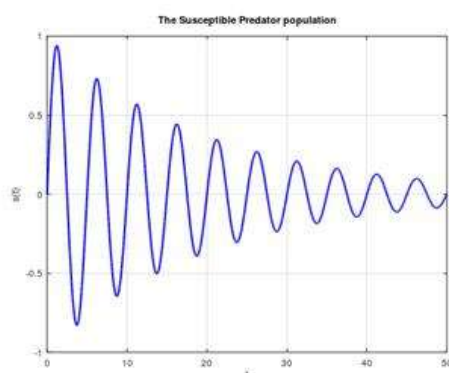


Figure.1: The Susceptible Predator Population

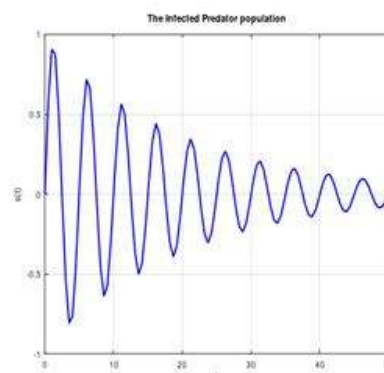


Figure.2: The Infected Predator Population





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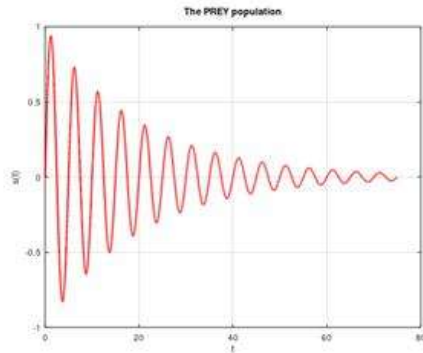


Figure.3: The Prey Population

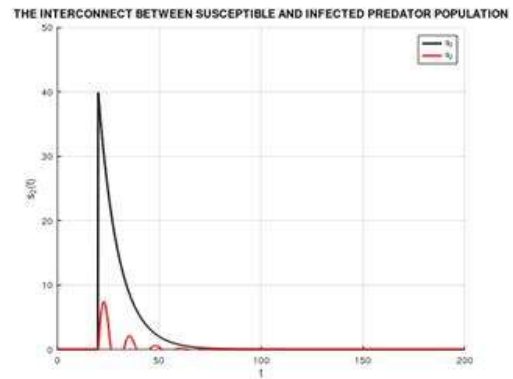


Figure.4: The Interconnect between Susceptible and Infected Predator Population

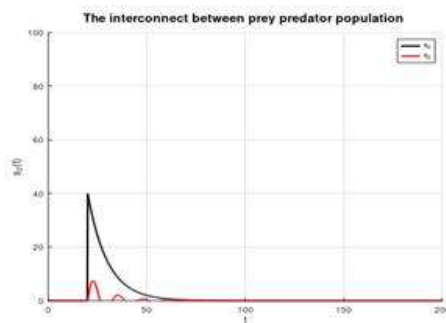


Figure.5: The Interconnect between Prey-Predator Population





Green HR: Empowering Circular Economies through People and Processes

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ABSTRACT

Today, sustainability is the core constituent of organisations aiming to achieve long-term success in this fast-changing business world. CEM is a practical method of waste minimization and maximum use of resources. The role of HR in CEM is to create a culture of teamwork and continuous improvement among employees in delivering Customer Experience Management. There are certain changes that occur in the basis of change attractiveness and retention capacity on the one hand and decreases negative impacts on the environment, and so this calls for the implementation of Green HR practices. A major study comprising 276 participants affirms the strong link between the performance of CEM and Green HR practices promoting people-oriented initiatives toward sustainable growth. Results of this study offer practical guidance for firms wishing to harness their human resources toward making them environmentally friendly to heighten their efficiency in operations.

Keywords: Circular Economic Models (CEM), Sustainability, Circular Economy, Green HR, Innovation, Resource Efficiency, Organizational Growth





INTRODUCTION

In today's fast pace business environment sustainability has evolved from the periphery to the centre as a driver of innovation and organizational success. The most relevant consequences are the adoption of circular economic models into the business practices of companies, by design they focus on resource efficiency and waste reduction in their applications. Here, the HR department has become very important in this new trend. As part of the basis for people-focused processes that form a template of sustainable business models, it deals with Green HR, which brings sustainability into the fold of HR strategy, and its role in supporting circular economies so as to enhance environmental stewardship and operational efficiency.

The Role of HR in Fostering Circular Economies

Strategic Recruitment and Talent Management

The Human Resources department plays a basic role in the selection process to identify candidates with suitable competencies and to the commitment to sustainability. The human resources department is responsible for ensuring that the workforce shares the sustainability goals of the organization as it prefers candidates whose competencies are relevant to sustainability. According to Kramar (2014), it illustrates the role human resources can play in developing strategies of recruitment in terms of eco-competencies that can convert individuals into assets in the form of a circular economy. Green HR refers to sustainability integration in the strategies and practices of human resource management. Shah et al. (2021) found that integrated organizations in human resource functions for sustainability objectives are better in creating an environment with responsible employees toward environmental protection. Strategic integration through this may help develop a competent committed staff toward ecologically sustainable activity.

Employee Training and Development

Training programmes need to be sustainable for employees to acquire knowledge of environmentally friendly practices. This role is under Human Resources to design the training programs that enhance the knowledge and skills of employees concerning the sustainability of their work. According to Ehnert (2009), quality training in the use of sustainable practice allows the employees to integrate appropriate principles related to these practices into their daily work activities, which in turn encourages an organizational culture that accommodates circular initiatives. In ensuring that CEM achieves its success, there will be a need to hire people with the appropriate knowledge on sustainability. According to Cascio and Montealegre (2016), organizations that concentrate hiring people with eco-competencies apply circular practices more efficiently. Human resources can support newly hired people making positive implications toward the environment through adding inputs of sustainability in job descriptions and hiring activities.

Performance Management Systems

One of the ways that human resources can integrate sustainability into performance management in an organization is through using metrics that measure employees according to their contributions to sustainability objectives. Jackson and Seo discuss the relevance of tying performance measures to sustainable activities as well as rewarding environmentally friendly behaviors and outcomes, especially as detailed in the 2010 research. Linking these measures serves to encourage people but also underscores the organization's commitment to responsible environmental practices. The proper trainings for the employees support the culture of sustainability in business. The display of the eco-competency of personnel can be created through the trainings by focusing on sustainable practices. The training of a relevant and effective program helps individuals more profoundly understand the principles of the circular economy. Businesses strengthen the principles through the deployment of opportunity for employee seminars and courses focused on resource management, trash reduction, and specific recycling techniques. Transparency with metrics in Human Resources can link sustainability with performance management as the former entity gives an easily pursued approach in which the organization applies measurable methods for it to assess its employees and their efforts towards environmental cause. Dumont *et al.* (2017) further stated that Inside the company's door,



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sustainable practices could be encouraged by rewarding employees who carry out environmentally conscious acts. It thus links employee engagement with the development of organizational performance towards sustainability.

Fostering an Innovative Culture

The Human Resource department is the most significant enabler in building an innovative culture where there is collaboration and creative problem-solving concerning sustainability issues among employees. The Human Resource department can help engender the establishment of creative solutions embracing the circular economy model (CEM) by encouraging a culture of continuous improvement. According to Govindan and Hasanagic, "sustainable supply chain management requires proper assistance from a constructive and supportive corporate culture.". Human resources can individually affect the attitude of an organization's culture for sustainable success in executing the sustainability initiatives. Human resources might encourage the employees to embrace sustainability as a value by making an environment conducive to cooperation, ingenuity, and continuous improvement (Benn et al., 2014). The cultural revolution embedded in this attitude is more useful for the implementation of circular economy principles.

Employee Engagement and Empowerment

Employees are made to feel committed to the organizational goals whenever they are given the opportunity to participate in activities related to sustainability. Human Resources can encourage employees to participate in environmentally friendly initiatives to make them feel responsible for those initiatives. According to Ellen MacArthur Foundation, 2013, everyone working in the company should have an opportunity to participate to make the circular economy principles work effectively and smoothly.

Communication and Change Management

Effective communication is the critical element that ensures there is a change to become sustainable. Human Resource possesses the ability to lead efforts towards clearly communicating to all employees why sustainability and circular economy are essential. Human Resource can help to overcome potential resistance to change while aligning corporate efforts toward common goals through clear communication and demonstration of how sustainability issues benefit the company. Communication plays an essential role in enhancing sustainability goals and motivating the staff to be on board. While implementing change management, the Human Resources may embrace the training of the organization on its sustainability goals as well as how it can also be incorporated in its achievement by the employees. As in Dumont et al., proper communication allows a space for the employees to contribute to achieving the sustainability goals.

Metrics and Evaluation

Human resource management departments need to develop measures that will assist them in evaluating the success of their sustainability projects. That is, the organization needs to measure how much their employees are engaged in implementing environmentally friendly practices and evaluate how the training program has affected the sustainability goals of the organization. Ehnert (2009) believes that the use of metrics can be utilized to understand whether the initiatives by human resources result in creating a more sustainable environment or not and should inform future strategies. Defining metrics can be an effective method to gauge the overall performance of sustainability initiatives. The HR department will track the participation of employees in green-related activities and evaluate the effectiveness training sessions have in the attainment of sustainability objectives. Shah et al. (2021) Defined measures aid in knowing how well human resource management is working to achieve sustainability objectives and help in planning even more effective future strategies.

Theories and Frameworks in Green HR and Circular Economy

Green human resources are supported by numerous theories and conceptual frameworks with their relationship with the circular economy.



**Patcha Bhujanga Rao *et al.*,****Resource-Based View (RBV)**

The Resource-Based View, first suggested by Barney in 1991, emphasizes that businesses can create sustainable competitive advantage through the management of valuable, rare, and distinctive resources. Work such as Hart and Dowell in 2011 has brought to light eco-competencies as strategic advantages. Reinforcing the skills of the employees in sustainable capabilities proves that the organization commits itself not only to sustainable practice and circularity but also sets its eco-competency asset in an increasingly competitive surroundings.

Sustainable HRM Framework

Ehnert (2009) and Kramar (2014) have contributed significantly to the establishment of the Sustainable Human Resource Management Framework since it focuses on the integration of sustainability in HRM practices. In recent studies, however, Jabbour *et al.* (2019) emphasized the need for alignment of human resource policy to the objectives of corporate sustainability. In this regard, an integrated approach assists in achieving a sustainable culture within the workforce on a large scale because the policies concerning HR must be in concert with the environment-friendly larger goals of an organization.

Circular Economy Model (CEM)

In recent sustainability discussions, the Circular Economy Model has gained much interest. Most scholars of present times, like Kirchgeorg *et al.* (2018), state that closed-loop systems need to be developed, where materials are regularly recycled, remanufactured, and reused. The last study by Govindan and Hasanagic (2018) exhibits how human resources could incorporate circularity into the culture of an organization. Human Resources plays an important role in the development of circular economies as they urge the involvement of employees with issues of sustainable development.

Triple Bottom Line (TBL)

The economic, social, and environmental dimensions of organizational performance have been accepted widely in the contexts of the Triple Bottom Line model, because contemporary scholarly work illustrates how human resources promote this balance and emphasizes responsible environmental stewardship mostly through employee welfare issues. This can open a path for companies developing a sustainable and socially conscious operating model.

Institutional Theory

This rediscovered interest in Institutional Theory in the sphere of sustainability attempts to understand the manner in which organisations react to external pressures. New research by Waddock and Googins (2019) reveals that human resources play a crucial role in aligning organizational practices with the statutory, normative, and cultural needs. Aligned to such means improves compliance and brings in a culture favoring sustainability initiatives, which is of high value to companies in dealing and making decisions in such an evolving regulatory framework on matters of sustainability.

Literature Review: Green HR Empowering Circular Economies Through People and Processes

Recently, the sustainability discourse has been very rich in the context of integrating Green Human Resources with Circular Economy Models. More and more businesses have come to realize that sustainable practices are not only ethically imperative but also ensure the long-term sustainability of the business ventures. Green human resource management forms an essential tool for infusing the ideals of ecological sustainability into the culture and practice of the workplace operations. Ehnert (2009) first addressed the sustainability of human resource management wherein this concept discussed the alignment of the functions of human resources with the sustainability objectives. Kramar (2014) extended this idea by explaining how adding sustainability into the HR strategy may add value to company performance. Recent studies also highlighted the strategic importance of human capital towards achieving sustainability goals. According to the Resource-Based View developed by Barney in 1991, human capital could be an important source for competitive advantage. Recent studies such as Jabbour *et al.* (2020) prove that Green HRM practices which support eco-competencies can make employees valuable assets in the course of achieving sustainability.



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A relevant concept that surfaces here is the need for employee engagement. According to the views of Daily and Huang (2001), cultivating the sustainability culture boosts staff commitment, which is critical in the successful achievement of circular economy principles. Under this context, a new study by Dutta *et al.* (2019) shows that green human resource practices encourage collaboration, an essential factor for attainment under sustainability goals. For example, the contribution of training and development in arming employees with the necessary sustainable practices has been overstated. According to Renwick *et al.* (2013), firms that focus on green training programs experience increased employee engagement in sustainability practices. In this regard, training and development is essential to arm employees with necessary sustainable practices. According to Zafar *et al.* (2021) "Education, especially ongoing, transforms them toward their active involvement in sustainability projects". For example, much attention has recently been concentrated on considering how sustainability criteria can be integrated into performance management systems. Several studies conducted by different scholars, such as Govindan and Hasanagic (2018), indicated that the acknowledgment of efforts by employees toward sustainability may significantly increase employee motivation to consider environmental issues in their work. In this respect, a recent study by Jabbour *et al.* (2020) appears to corroborate the mentioned perspective, suggesting that high performance management is likely to enhance employees' involvement in the organisational initiatives aimed at sustainability. However, in this literature, the issues of resisting change and inadequate support of management are considered. In this respect, Jackson *et al.* 2012 and Sharma & Kumar 2018 consider such issues and emphasize the importance of strong organizational commitment to overcome them. Although there are many benefits of Green HR, such practices need to be tested for their effectiveness. Recent research has challenged empirical studies to establish explicit links between green human resource initiatives and organisational performance with regard to the practice of circular economies. The study done shows that Green HR significantly facilitates circular economies through strategic and people-centric practices. Integrate sustainability with a human resource strategy, and then the organization can develop a system that balances input and output, instilling a culture of environmental stewardship within it, thereby aiding in the improvement of the long-term performance of the organization. Problems that are longstanding require further investigation in longitudinal assessments of green human resource practices and what leadership does towards this end, and such would bring out much more valuable insights in how good implementation strategies work. This dynamic climate points towards organizational apparatuses that must continuously innovate themselves, creating a human resource strategy in line with the larger sustainability goals it espouses.

Case Studies in Sustainability and Human Resource Management

During the analysis of the intersection between human resource management (HRM) and sustainability, some businesses have distinguished themselves as pioneers in integrating sustainable practices into their business strategies. These organisations have effectively integrated sustainability into their human resource strategies and corporate cultures, as evidenced by the case studies provided below.

Unilever's Sustainable Living Plan

A Plan for Sustainable Living Initiated by Unilever, 2010 heralded the launch of the Sustainable Living Plan, designed to mitigate the company's environmental footprint while enhancing its societal effect. This initiative integrates corporate culture with sustainability by emphasising sustainable sourcing and waste reduction. The Human Resource Management function significantly contributes to fostering a culture dedicated to sustainability via the execution of specialist training and development programs. The findings suggest a significant correlation between human resource management practices and the outcomes of sustainability programs, indicating that this commitment has enhanced employee morale and boosted productivity (Unilever, 2010).

Interface Inc.

Interface Inc., a global pioneer in modular carpet production, has been committed to sustainability since the 1990s and aimed to have zero negative environmental effect by 2020. A culture of environmental responsibility has emerged due to the company's success in integrating sustainability into its human resource policy and employee engagement strategies. Research has revealed that Interface's commitment to sustainability has led to substantial cost



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savings and innovation in product design. This illustrates that a robust commitment to sustainability may foster employee loyalty and satisfaction (Interface Inc., 2017).

Patagonia

Patagonia is renowned for its dedication to social responsibility and involvement in the environmental movement. The organisation promotes employee involvement in environmental initiatives by integrating sustainability into its business strategy. Patagonia's commitment to corporate social responsibility (CSR) not only strengthens the company's culture but also enhances employee satisfaction, as seen by this case study. The company's emphasis on employee involvement in environmental initiatives has resulted in notable levels of engagement, underscoring the benefits of aligning corporate principles with employee actions (Patagonia, 2018).

Siemens

Siemens is dedicated to reducing carbon emissions and advancing eco-friendly technologies throughout its operations, having initiated comprehensive sustainability initiatives to realise these objectives. The strategic significance of human resource management in advancing sustainability initiatives is evidenced by the alignment of HR practices with the firm's sustainability objectives. The integration of sustainability into Siemens' business strategy has led to heightened employee engagement and an improved corporate reputation (Siemens AG, 2016). These results illustrate the capacity of human resources to serve as a catalyst for sustainability efforts.

Walmart's Sustainability Index

The Sustainability Index was established by Walmart in 2009 to enhance transparency and reduce the environmental impact across its supply chain. Human resource management will significantly contribute by facilitating staff training on sustainability practices. This program aims to assess the sustainability of products and providers. The results indicate that educating employees on sustainability has led to enhanced operational efficiency and an improved corporate image, demonstrating how human resource management can advance sustainability within an organisation (Walmart, 2009). The case studies of Unilever's Sustainable Living Plan, Interface Inc., Patagonia, Siemens, and Walmart's Sustainability Index illustrate how effective human resource management strategies may enhance sustainability initiatives and increase employee engagement. By integrating sustainability into its core business strategy, Unilever fosters a culture of responsibility that empowers employees to contribute to social and environmental achievements. To promote a circular economy, Interface Inc. urges its employees to engage in innovative sustainability activities. This thus enhances job satisfaction and fosters a favourable reputation for the organisation. Patagonia is dedicated to environmental responsibility across its staff, driven by the company's objectives. The firm promotes its employees to champion sustainable practices, therefore strengthening their commitment to the brand. Siemens prioritises sustainability by offering training and development opportunities to its workers, therefore cultivating a workforce that is knowledgeable and committed to sustainable innovation. The final reason is that Walmart's Sustainability Index promotes employee engagement in supply chain transparency, therefore enhancing the company's image and providing a heightened feeling of purpose. The cumulative impact of these initiatives illustrates that aligning human resource management with sustainability objectives enhances the company's reputation while also fostering employee engagement and commitment to environmental stewardship.

Objectives

1. To examine the influence of Green HR practices on the successful implementation of Circular Economy Models.
2. To explore the role of employee engagement in promoting sustainability within CEM frameworks.
3. To identify the relationship between eco-friendly HR policies and organizational resource efficiency.
4. To assess the impact of Green HR initiatives on employee performance and innovation.
5. To propose strategies for enhancing Green HR to foster circular economies.



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1. **H01:** There is no significant relationship between Green HR practices and the implementation of CEM.
2. **H02:** Employee engagement in Green HR initiatives does not significantly influence organizational resource efficiency.
3. **H03:** Eco-friendly HR policies do not significantly impact employee innovation and performance.
4. **H04:** The integration of Green HR into organizational processes has no significant effect on the success of circular initiatives.
5. **H05:** There is no significant correlation between sustainability training programs and the reduction of waste in circular economies.

Primary Study

The baseline study involved 276 respondents cut across several industries and were undertaking sustainability activities. The following section is a summary of the demographic information, which includes gender, age, industry, and organizational status. This content is geared to better understand how demographic characteristics may impact the interpretation of Green HRM practices and CEM results. This information provides critical descriptive insight into the research population. Report: The data was collected through a survey as part of the research report

Key Insights

The survey has nearly equal male to female ratio, so it also holds gender parity, which may reflect gender-related views on green human resource strategies and the same set of concerns regarding sustainability. Analyzing the distribution of ages, it can be judged that there are more people belonging to the 31-40 years age group, thus amounting to 40.6% of the total; 27.2% belong to the age group of 20-30 years. It may be true that younger professionals will exercise more influence in the perception and adoption rates of green human resource management in the organisations due to the overall shifting of the generation towards increased environmental consciousness. The manufacturing sector accounts for 36.9%, followed by services at 32.2%, and information technology at 30.8%. Such vast industrial spread involved in this discussion allows the impact of Green HR across multiple industries to be measured. The largest number of middle-management job people indicates that those persons associated with the organizational decision-making are responsible for judging the green human resource policies. 45.2% of respondents fall in this category.

Data Collection Methods**Questionnaires and Interviews**

Questionnaires and interviews were used to collect data through standardized methodologies. Data collection mostly focused on green human resource practices, which include green recruiting, training, and performance management, and the CEM role these play. The richness of such methods ensures full enlightenment of the role that Green HR plays in organizational sustainability. The questionnaires helped in ascertaining the attitude of the respondents towards green human resources and their relevance to sustainability. Questions would be designed through a five-point Likert scale. Some of the questions would include those towards engagement in environmental-friendly activities and rating of the organization's effectiveness in CEM. The qualitative data obtained from interviews enriched the results drawn from the quantitative setup. The interviews provided a very deep insight into the employees' experience and viewpoint about green human resource strategy. Utilizing mixed methods in this study will enhance the reliability and comprehensiveness of findings on this topic, as it accounts for statistical trends and individuals' perspectives both simultaneously.

Analysis

The detailed analysis of survey results on Green Human Resource (HR) practices, focusing on the perceptions and attitudes of employees across multiple organizations. The analysis covers four key areas: Green Recruitment, Green Training, Green Performance Management, and Overall Perception of Green HR Practices. Data from a Likert-scale questionnaire was used to evaluate the effectiveness and integration of these practices within organizations. The results are presented through tables and interpretations, alongside hypothesis testing and comparative analyses.



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Overall Perception of Green HR Practices: Mean Average is 3.48, which signifies that all the respondents have a positive general perception about the actions of Green HR in the organization. The lowest mean score came from Green Performance Management with 3.20. It therefore hints at the scope for its improvement in the integration of sustainability to be included in performance measurement. On all dimensions, a great deal of variation was reported in the answers. The smallest variation for Green Performance Management came as only 0.14, suggesting that consensus was greater on the specific issue.

Hypothesis Testing

The data indicate a significant positive association ($p < 0.05$) between Green Recruitment and organisational sustainability. This conclusion confirms that Green Recruitment significantly contributes to the company's sustainability initiatives. Findings of the study show a statistically significant positive correlation between Green Training and resource efficiency at $p < 0.05$ level. The study points out the role training plays in achieving organisational sustainability objectives. This has been reflected in the results, where there has been a significant positive relationship between Green Performance Management and employee creativity, with $p < 0.05$, indicating that incentivising sustainable practices may help enhance innovative behavior on Green HR Practices.

Interpretation

Strong positive correlations suggest that organizations prioritizing Green HR practices are more successful in implementing circular economy initiatives.

The results of mediation research suggest a significant mediation effect of employee engagement on the relationship between green human resource practices and organizational innovation. Employees engaged at work are going to enhance the effectiveness of green human resource efforts.

Findings from Hypothesis Testing**Hypothesis 1 (H1): Green Recruitment has a significant positive effect on organizational sustainability :**

The analysis indicates a coefficient of 0.45 for Green Recruitment, accompanied by a p-value of 0.001. This result confirms a significant positive effect on organizational sustainability.

Hypothesis 2 (H2): Green Training has a significant positive effect on resource efficiency:

The coefficient for Green Training is 0.38, with a p-value of 0.002, demonstrating a significant positive relationship with resource efficiency.

Hypothesis 3 (H3): Green Performance Management has a significant positive effect on employee innovation:

The coefficient for Green Performance Management is 0.30, with a p-value of 0.003. This finding indicates a significant positive effect on employee innovation.

Hypothesis 4 (H4): Employee engagement mediates the relationship between Green HR practices and organizational innovation:

The direct effect is measured at 0.40, while the indirect effect is 0.36, both with p-values less than 0.001. These results confirm that employee engagement significantly mediates the relationship between Green HR practices and organizational innovation.

Hypothesis 5 (H5): There is a significant positive correlation between Green HR practices and CEM success:

The correlation coefficients of 0.78, 0.72, and 0.68 for the respective variables indicate strong positive correlations, affirming a significant relationship between Green HR practices and CEM success.





CONCLUSION

Conclusion The results give strong evidence for all hypotheses that were tested. All the hypotheses have a p-value of less than 0.05, so we accept them separately. Green Recruitment is highly impactful on organizational sustainability initiatives. Green Training has been found to be highly effective at promoting efficiency in resource use. Furthermore, the findings also present the fact that Green Performance Management greatly impacts employee creativity in terms of rewards for environmentally friendly practices. Further, there is an indication from the p-values that the mediation between the variables is significant. This means that employee engagement has a positive effect enhancing the efficacy of green human resource policies on organizational innovation. Such results point to the need to integrate green human resource initiatives into organizational strategies to foster innovation and sustainability.

Implications to Society

It, therefore, shows that Green HR practices enhance sustainability and innovation within firms. This, therefore, yields big time societal benefits. The use of Green Recruitment adds increased dimensions of sustainability to organisations and encourages an eco-friendly workforce. Thus, the workforce can henceforth go a long way in illustrating increased environmental awareness, help in their communities, and developing social change. Green Training maximizes the efficiency of resources utilized to produce a good or service, thereby reducing waste and conserving resources. Improved operational methodologies can reduce footprints, which indirectly support the society by giving it a healthy environment. Green Performance Management also promotes sustainable innovation. In this case, the organization rewards employees for their environmentally friendly behaviors, encouraging creative solutions that are ecological and facilitating improved technologies and practices that benefit the interest of society. Finally, because employee engagement mediates these processes, a culture of involvement and commitment can enhance Green HR practices. An engaged employee tends to advocate for sustainability both within and beyond their organizations, thus leading to a greener future. Green HR practices improve organizations and society by encouraging a culture of sustainability that can strengthen environmental health and community resilience.

Future studies

Some other themes to be studied on Green HR practices in relation to sustainability and performance at the organizational level include: Longitudinal studies can provide a more potent uncovering of how the cumulative effects of Green HR activities take place over time to foster an in-depth appreciation of how such efforts might affect organizational culture as well as environmental consequence over a prolonged duration. Besides these, further research will be conducted by considering more industries and different geographic locations to give value to the findings based on applicability. Comparative analysis among sectors could disclose certain particular problems and best practices unique to other contexts, helpful in formulating sector-specific strategies for effective implementation of Green HR practice. Relations involving technology and Green Human Resource Management could be studied in future. Assessing the impact of digital tools and data analytics application on improving Green HR metrics such as hiring, training, and performance management may introduce some new ideas.

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Table.1: Demographic Factors of the study

Demographic Factor	Categories	Frequency	Percentage (%)
Gender	Male	134	48.6
	Female	138	50.0
	Others	4	1.4
Age	20-30	75	27.2
	31-40	112	40.6
	41-50	64	23.2
	51+	25	9.0
Industry	Manufacturing	102	36.9
	IT	85	30.8
	Services	89	32.2
Position in Company	Entry-level	87	31.5
	Mid-level	122	44.2
	Senior-level	67	24.3

Report: The data was collected through a survey as part of the research report

Table.2: Descriptive Statistics for Each Factor (N = 276 Respondents)

Factor	Mean	Std. Dev.	N
Green Recruitment	3.37	0.15	276
Green Training	3.45	0.18	276
Green Performance Management	3.20	0.14	276
Overall Perception of Green HR Practices	3.48	0.17	276

Source: Research Compilation

Table.3: Regression Analysis for Green Recruitment and Organizational Sustainability Tests Hypothesis 1 (H1): Green Recruitment has a significant positive effect on organizational sustainability.

Variable	Coefficient	Standard Error	t-Statistic	p-value
Green Recruitment	0.45	0.10	4.5	0.001
Constant	2.00	0.50	4.0	0.002

Source: Research Compilation

Table.4: Regression Analysis for Green Training and Resource Efficiency Tests Hypothesis 2 (H2): Green Training has a significant positive effect on resource efficiency.

Variable	Coefficient	Standard Error	t-Statistic	p-value
Green Training	0.38	0.12	3.17	0.002
Constant	1.80	0.60	3.0	0.003

Source: Research Compilation





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Table.5: Correlation Analysis for Green HR Practices and CEM Success Tests Hypothesis 5 (H5): There is a significant positive correlation between Green HR practices and CEM success.

Variables	Correlation Coefficient (r)	Interpretation
Green Recruitment & CEM Success	0.78	Strong Positive Correlation
Green Training & Resource Efficiency	0.72	Strong Positive Correlation
Green Performance Management & Employee Innovation	0.68	Strong Positive Correlation

Source: Research Compilation

Table.6: Mediation Analysis for Employee Engagement Tests Hypothesis 4 (H4): Employee engagement mediates the relationship between Green HR practices and organizational innovation.

Pathway	Coefficient	p-value
Green HR → Employee Engagement	0.58	<0.001
Employee Engagement → Organizational Innovation	0.62	<0.001
Direct Effect (Green HR → Innovation)	0.40	<0.001
Indirect Effect (Green HR → Engagement → Innovation)	0.36	<0.001

Source: Research Compilation

Table 7: Regression Analysis for Green Performance Management and Employee Innovation Tests Hypothesis 3 (H3): Green Performance Management has a significant positive effect on employee innovation.

Variable	Coefficient	Standard Error	t-Statistic	p-value
Green Performance Management	0.30	0.10	3.0	0.003
Constant	1.50	0.50	3.0	0.004

Source: Research Compilation





Solid Lipid Nanoparticles: Formulation, Evaluation and Encapsulation Strategies for Synthetic and Herbal Compounds - An Overview

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ABSTRACT

Solid lipid nanoparticles (SLNs) present a modern approach to overcome limitations in conventional drug delivery by facilitating controlled release, enhanced absorption, and improved bioavailability. With applications across both pharmaceuticals and nutraceuticals, SLNs stand out as transformative technology in these fields. Encapsulating bioactive herbal compounds within SLNs can notably boost their therapeutic effects, leading to more effective treatments. This review provides a comprehensive overview of SLN technology, focusing on its benefits and various preparation techniques, such as high-pressure homogenization, solvent evaporation, ultrasonication, microemulsion, solvent injection, double emulsion, and spray drying. It also examines essential methods for evaluating and characterizing SLNs and explores encapsulated molecules, including natural biomolecules, emphasizing the potential of SLNs to advance herbal medicine. The integration of SLN technology into product formulations opens new avenues for developing efficient, reliable, and clinically potent therapies. In summary, solid lipid nanoparticles represent a significant breakthrough in encapsulating and delivering bioactive substances, promising considerable advancements in pharmaceutical including herbal and nutraceutical development.

Keywords: Bioavailability, Controlled release, Homogenization, Solvent evaporation, Ultrasonication, Microemulsion.





INTRODUCTION

Solid lipid nanoparticles are submicron-sized particles composed of biocompatible and biodegradable lipids, which encapsulate active pharmaceutical ingredients, enhancing their delivery and effectiveness [1]. Developed in the early 1990s, SLNs have been regarded as promising drug carrier systems, particularly for providing a sustained release profile to incorporated active substances [2]. SLNs have become a hot topic in drug research due to their unique properties and potential to overcome limitations of conventional drug delivery methods. Here's a deeper dive into their significance in the current research landscape: They offer numerous advantages, including improved bioavailability, controlled release, and enhanced stability of therapeutic agents [3]. Solid lipid nanoparticles are nanoparticles mean diameter ranging approximately between 50 and 1000 nm by photon correlation spectroscopy (PCS). The general ingredients of SLNs include solid lipid, surfactant and water. The term lipid here is broadly defined and encompasses triglycerides (e.g., tristearin), partial glycerides, fatty acids (e.g., stearic acid), steroids (e.g., cholesterol), and waxes (e.g., cetyl palmitate). Various classes of surfactants, irrespective of charge and molecular weight, have been utilized to stabilize the lipid dispersion. SLNs offer better biocompatibility, because they are composed of lipids similar to physiological ones, resulting in reduced toxicity. Furthermore, SLNs are physico-chemically stable, easily producible on a large industrial scale, and have relatively low raw material and production costs [2]. This review delves into the current status of SLN technology in drug research, discussing their design, preparation, characterization, and application across various therapeutic areas. Herbal medicines have been a cornerstone of healthcare for centuries. However, the clinical efficacy of many herbal ingredients is often limited by poor solubility, stability, and bioavailability. Traditionally, herbal medicines have been formulated as tablets, capsules, and decoctions; however, these methods have not succeeded in enhancing the bioavailability of these medicines. Excitingly, nanotechnology has made significant progress in boosting the effectiveness of herbal medicines and overcoming biological barriers by improving their bioavailability [4]. Solid lipid nanoparticles provide a promising solution to these challenges, enhancing the delivery and therapeutic efficacy of herbal products. This review explores the advantages of SLN technology in the formulation of herbal products, highlighting its potential to revolutionize the field of herbal medicine.

Key advantages of SLNs

Biocompatibility and Biodegradability: SLNs are composed of lipids that are both biocompatible and biodegradable, ensuring no bio toxicity.

Organic Solvent-Free Production: SLNs can be produced without the use of organic solvents. So the chances of toxicity is minimised.

Controlled and Targeted Drug Delivery: SLNs facilitate both drug targeting and controlled drug release.

Enhanced Stability of Active Compounds: Incorporating active compounds into SLNs enhances their stability.

Encapsulation Versatility: SLNs can encapsulate both lipophilic and hydrophilic drugs.

Scalable Production: SLNs can be easily produced on a large scale.

Sterilization Capability: SLNs can be sterilized effectively [5]

Limitations of SLNs

Limited Drug Loading Capacity with Crystalline Lipids: The incorporation of crystalline lipids can restrict the amount of drug that can be loaded into SLNs.

Risk of Drug Leakage from Lipid Structures: Certain crystalline lipid modifications, particularly β -modifications, may lead to the leakage of encapsulated drugs.

Gelation During Storage: Over time, SLNs may transition to a gel-like state, potentially impacting their stability and usability.



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Stability Issues from High Water Content: The presence of high water content (70–90%) in SLNs can create stability challenges.

Factors Affecting Drug Loading: The efficiency of drug loading into SLNs is influenced by various factors, including the interaction between the drug and the lipid matrix, the characteristics of the lipid used, and the solubility and distribution of the drug within the lipid [6].

Design

Structure and Composition: SLNs are typically composed of solid lipid cores stabilized by surfactants. The core can be made from a variety of lipids, such as triglycerides, partial glycerides, fatty acids, steroids, and waxes. The surfactants, which can be ionic or nonionic, stabilize the lipid core and prevent agglomeration [7].

Preparation of Solid Lipid Nanoparticles

The preparation of solid lipid nanoparticles (SLNs) involves several fundamental principles aimed at producing stable, biocompatible, and efficient drug delivery systems. These principles include the selection of appropriate lipid materials, surfactants, and preparation methods.

Selection of Lipid Materials

The core material for SLNs is typically composed of solid lipids that are biocompatible and biodegradable. These can include: Glycerylbehenate (Compritol), Glycerylpalmitostearate (Precirol), Stearic acid, Palmitic acid, Triglycerides [8].

Criteria for Lipid Selection

The selection of a solid lipid or lipid blend relevant to SLN generally depends on several factors:

- Solubility
- The ability to produce particles in the submicron range
- Biodegradability
- Biocompatibility
- Adequate drug carrying capacity
- Storage stability [2].

Selection of Surfactants

These are crucial for stabilizing the SLNs and preventing aggregation [9]. Common surfactants include: Polysorbates (e.g., Tween 80), Polyethylene glycols (PEG), Phospholipids (e.g., lecithin), Bile salts (e.g., sodium cholate) [10].

Criteria for Surfactant Selection

- Biocompatibility and low toxicity
- Ability to reduce interfacial tension between lipid and aqueous phases.
- Compatibility with the drug and lipid matrix [11].

SLN PREPARATION METHODS

Precursors

Emulsions serve as precursors for solid lipid particle preparation because lipids, which are solid at room temperature, can be heated 5-10 °C above their melting point to become liquid. This liquid lipid is then emulsified with water at the same temperature. The resulting hot emulsion is cooled to room temperature, causing the droplets to solidify into solid lipid particles. The size of the hot emulsion droplets determines whether nano- or microparticles are formed. Solid lipid nanoparticles (SLNs) can be produced from hot O/W nanoemulsions (with droplet sizes less than 1 µm) using the hot homogenization technique. This technique can be performed using various methods, including high-pressure homogenization, high-shear homogenization, and ultrasound homogenization [2].





High-Pressure Homogenization (HPH): This technique produces submicron particles through high shear stress and cavitation by forcing liquids at pressures between 100 and 2,000 bar through a narrow gap, causing the fluid to move rapidly over a short distance. This process can transform even high lipid concentrations into nanodispersions. SLNs can be produced using both hot and cold homogenization techniques, each starting with a preparatory step [9].

Hot Homogenization: In hot homogenization, temperatures above the lipid's melting point are used, making it similar to emulsification. An aqueous surfactant combines with the lipid and drug at the same elevated temperature. A high shear mixing device prepares a hot pre-emulsion, creating an oil-in-water type emulsion. This emulsion is then cooled, initiating lipid crystallization and forming SLNs. To produce optimal SLNs, 3-5 cycles of homogenization at pressures between 500 and 1,500 bar are required [12]. High-pressure homogenization is one of the most widely used methods for the preparation of SLNs.

Cold Homogenization: Cold homogenization was developed to overcome the significant drawbacks of the hot homogenization method, which include drug degradation due to high temperatures, drug distribution into the aqueous medium, and the complex process of nanoemulsion crystallization that leads to multiple changes and/or supercooled melts. Cold homogenization technology (CHT) helps prevent or reduce lipid melting, thereby limiting the degradation of hydrophilic drugs during the aqueous process. In cold high-pressure homogenization (HPH), the drug is first dissolved in molten lipids and then the mixture is rapidly cooled using liquid nitrogen or ice. This quick cooling allows for a homogeneous dispersion of the drug within the lipid matrix. The resulting lipid-drug mixtures are ground to a particle size (PS) of 50–100 μm using a ball mill or mortar. These lipid microparticles are then suspended in surfactant-containing cold aqueous solutions and further homogenized at cold temperatures (e.g., 0–4 $^{\circ}\text{C}$) typically over 5–10 cycles at 500 bar [13].

Microemulsions and SLN Production

Microemulsions come in three basic types: direct (O/W), reversed (W/O), and multiple (W/O/W and O/W/O). Hot microemulsions can serve as templates for solid lipid nanoparticle production. In this method, the oil phase consists of a solid lipid, liquefied above its melting point. SLNs can be produced by either diluting the hot microemulsion in cold water (microemulsion dilution technique) or simply cooling the hot microemulsion (microemulsion cooling technique). Due to their exceptional solubilization properties, microemulsions are increasingly recognized as potential drug delivery systems for active pharmaceutical ingredients (APIs) with poor water solubility. Furthermore, the excellent solubilization capacity of hot microemulsion precursors allows for effective drug loading within SLNs, particularly for drugs with poor water solubility [2].

Solvent Emulsification-Evaporation Method: The solvent emulsification-evaporation method, uses water-immiscible organic solvents like chloroform, cyclohexane, dichloromethane, and toluene to make solid lipid nanoparticles.

- Dissolving:** The drug and lipids are dissolved in an organic solvent or a mix of solvents.
- Emulsifying:** This solution is then mixed into an aqueous phase to create a dispersion of tiny particles.
- Evaporating:** The organic solvent is evaporated by mechanical stirring or using a rotary evaporator, causing the lipids to precipitate and form SLNs [14].

Solvent Emulsification-Diffusion Method: This method uses organic solvents that partially mix with water, such as methyl acetate, ethyl acetate, isopropyl acetate, benzyl alcohol, and butyl lactate.

Steps:

- Saturation:** The organic solvent and water are mutually saturated to reach thermodynamic equilibrium.
- Dissolution:** Lipids and drugs are dissolved in the water-saturated solvent.
- Emulsification:** This solution is emulsified in water containing a stabilizer, forming an oil-in-water (o/w) emulsion.





- d) **Dilution:** The emulsion is diluted with water (1:5 to 1:10 ratio), allowing the solvent to diffuse into the continuous phase.
- e) **Formation:** SLNs form as lipids precipitate. The solvent is removed by lyophilization or vacuum distillation [14].

Supercritical Fluid Extraction of Emulsions (SFEE): SFEE is a method to produce lipid nanosuspensions by extracting the organic solvent from oil-in-water (O/W) emulsions using supercritical fluids.

- a) **Preparation:** An O/W emulsion is created by dissolving lipid and drug in a volatile solvent like chloroform. This solution is then mixed into an aqueous phase containing a surfactant and passed through a high-pressure homogenizer to form fine emulsions with droplet sizes between 30–100 nm.
- b) **Extraction:** The O/W emulsions are fed into an extraction column from the top while supercritical CO₂, maintained at a constant pressure of 80 bar and a temperature of 35°C, is introduced from the bottom in a counter-current flow.
- c) **Process Conditions:** The pressure and temperature are carefully controlled to minimize the loss of lipids and drugs into the CO₂ phase while maximizing extraction efficiency. The entire process takes about two minutes, during which pure aqueous suspensions of SLNs are continuously collected from the bottom of the column.
- d) **Mechanism:** As the emulsion enters the supercritical CO₂ phase, the solvent is extracted into the CO₂, and CO₂ simultaneously enters the emulsion droplets. This causes the organic phase to expand, leading to the precipitation of the lipid-drug material as composite particles [2].

Spray Drying Method: The spray drying method is a cost-effective alternative to lyophilization for converting an aqueous SLN dispersion into a drug product. However, it can cause particle aggregation due to high temperatures, shear forces, and partial melting of particles [15].

Membrane Contactor Method: The membrane contactor technique is ideal for large-scale production of lipid nanoparticles due to its excellent scalability. It uses a straightforward apparatus to prepare solid lipid nanoparticles (SLNs) and allows for particle size control by carefully selecting process parameters like temperature and pressure.

Process Overview

- a) **Preparation:** The lipid phase, containing the drug, is melted, and the aqueous phase contains the surfactant.
- b) **Permeation:** The melted lipid phase is forced through a porous membrane under pressure, forming nanosized droplets.
- c) **Flow:** The aqueous phase flows tangentially within the membrane module, sweeping away the formed particles.
- d) **Solidification:** The aqueous phase is kept at the lipid melting temperature. SLNs form when the mixture is cooled to room temperature or maintained in a thermostatic bath [16].

Double Emulsion Method: The double emulsion method is used to produce SLNs for hydrophilic drugs and biomolecules like peptides and proteins. It's commonly used to incorporate insulin into SLNs.

Process Overview

- a. **First Emulsion:** Dissolve the drug and a stabilizer in an aqueous solution, then emulsify this mixture in a water-immiscible organic phase containing lipids or molten lipids.
- b. **Second Emulsion:** Disperse the primary water/oil (w/o) emulsion in an aqueous phase with a hydrophilic emulsifier to create a water/oil/water (w/o/w) emulsion.
- c. **Formation:** SLNs and NLCs form as the solvent evaporates, leading to lipid precipitation. The stabilizer helps prevent the drug from partitioning into the external water phase during this process [14].

High-Speed Stirring and Ultra-Sonication Methods: High-speed stirring (high-shear homogenization) and ultra-sonication are commonly used techniques for dispersing and producing SLNs. These methods are popular because they are simple and cost-effective.





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Process:

a. High-Speed Stirring

- i. Lipids are melted above their melting points.
- ii. Drugs are dissolved or dispersed in the molten lipids.
- iii. An aqueous phase with surfactants (at the same temperature) is added to the drug-lipid mix.
- iv. The mixture is dispersed using a high-shear mixer, creating a hot oil/water (o/w) emulsion.
- v. SLNs form when the emulsion is cooled.

b. Ultra-Sonication:

- i. This process follows high-speed stirring and involves using sound waves to break droplets by forming, growing, and collapsing bubbles.
- ii. When used alone, ultra-sonication can result in a broad particle size distribution because the energy is not evenly transferred.
- iii. There are two main sonication techniques for lipid dispersion:
 - i. **Probe-Tip Sonication:**
 - o Requires high energy for lipid dispersion.
 - o The sonicator probe's tip can cause a local temperature increase, so the reaction vessel should be immersed in a water or ice bath to control the temperature.
 - o Up to 5% of the lipids can deesterify during sonication (up to 1 hour).
 - ii. **Bath Sonication:**
 - o Temperature control is easier compared to probe-tip sonication.
 - o The sonicated SLNs can be kept in a sterile vessel, separate from the probe, or in an inert atmosphere.
- c. **Combined Use:** High-speed stirring and ultra-sonication are often combined to produce SLNs with narrow particle size distributions.

Advantages: Easy to handle and do not require organic solvents. Suitable for widespread use.

Disadvantages: Potential metal contamination from ultra-sonication probes (can be mitigated by using bath sonication). Requires high surfactant concentrations while maintaining low total lipid concentrations [14,16,17].

Stabilization And Storage

Ensuring the SLNs remain stable over time by optimizing surfactant concentration, lipid composition, and storage conditions. SLNs should be stored at controlled temperatures to prevent aggregation and maintain their integrity.

Evaluation - Characterization of SLNS

Particle Size and Distribution

The size and distribution of SLNs are critical parameters influencing their biodistribution, cellular uptake, and drug release profile. Dynamic light scattering (DLS) and transmission electron microscopy (TEM) are commonly used for size characterization [19].

Surface Morphology and Electron Microscopy

Electron Microscopy (EM): EM techniques determine the overall morphology of nanoparticles. These techniques are crucial in pharmaceuticals for drug release modulation and targeting [15].

Scanning Electron Microscopy (SEM)

Process: Nanoparticles are dried into powder, sprinkled on a sample holder, and coated with a conductive metal (like gold or platinum) using a sputter coater.





Mechanism

A high-energy electron beam is used to produce signals from the sample surface, generating images such as X-ray maps, backscattered electron images, and secondary electron images. Electron rays can damage particles, so the sample must withstand vacuum conditions.

Advancements

Environmental SEM (ESEM) allows scanning samples in their natural state without modification, using a low-pressure gaseous environment and eliminating the need for conductive coatings. Field Emission SEM (FESEM) was used to determine the surface morphology of nanoparticles [19-20].

Transmission Electron Microscopy (TEM)

Process: Uses electrons transmitted through the sample to form images, providing higher resolution than SEM.

Capabilities: Can study nanoparticles' morphology and chemical information at atomic dimensions (<1 nm).

Mechanism: An electron beam passes through a thin sample foil, creating images based on unscattered and scattered electrons. The image's resolution depends on the distance ratio between the objective lens and the specimen. High-level vacuum and thin specimen sections are needed. Samples are prepared with a negative staining solution (e.g., phosphotungstic acid) and dried under a mercury lamp.

Uses: High-resolution TEM can analyze local microstructures, such as lattice fringes and defects, at an atomic scale [21].

Surface Charge (Zeta Potential)

Zeta potential helps predict how stable a nanodispersion will be. A high zeta potential means the nanoparticles repel each other strongly, preventing them from clumping together. Conversely, a low zeta potential means attraction between particles outweighs repulsion, leading to clumping. Generally, a zeta potential above 30 mV is considered good for stabilizing a nanodispersion [22-23].

Drug Loading and Encapsulation Efficiency: Drug encapsulation efficiency (EE) is crucial for evaluating how well a drug is encapsulated. It is calculated using the formula:

$$EE\% = \frac{\text{Amount of entrapped drug}}{\text{Amount of total drug}} \times 100$$

To determine the encapsulated drug amount, UV-vis spectrometry or high-performance liquid chromatography (HPLC) is commonly used. A dialysis membrane can remove unencapsulated drugs, or ultracentrifuging can separate them. There are two main methods to measure EE: the direct method measures the drug in the nanoparticles directly, while the indirect method measures the unencapsulated drug in the supernatant and calculates EE. The direct method is better for lipophilic drugs, and the indirect method is better for hydrophilic drugs. A high EE is desirable for drug delivery. Several factors affect EE, including the type, composition, and crystallinity of lipid materials, and drug solubility in both organic and aqueous phases [18,24].

In vitro Release Studies

It assesses the drug release profile from SLNs under simulated physiological conditions. These studies help predict the in vivo performance of the nanoparticles and are typically conducted using dialysis methods or diffusion cells [25-26].

Encapsulation of Different Molecules In SLNs

Solid Lipid Nanoparticles (SLNs) are a versatile drug delivery system that can be used to encapsulate a wide range of molecules, including synthetic drugs, peptides, proteins, nucleic acids and herbal drugs. SLNs can improve the solubility, stability, and bioavailability of these molecules. Here are some examples of molecules that have been encapsulated using SLN techniques:



**Synthetic Drugs**

SLNs have been used to encapsulate various types of drug molecules, including Anticancer drugs: Paclitaxel, Doxorubicin, Camptothecin [27-29]. Antifungal agents: Itraconazole, Fluconazole [30-31], Anti-inflammatory drugs: Ibuprofen, Celecoxib [32-33], Antiviral drugs: Acyclovir, Zidovudine [35], Anti-hypertensive drugs: Amlodipine, Valsartan, etc [36].

Peptides and Proteins

SLNs can help stabilize and deliver delicate peptides and proteins. Examples include: Insulin [37], Growth factors: Insulin-like growth factor-1 (IGF-1), transforming growth factor-beta (TGF- β) [38], Antibodies and antibody fragments [39].

Nucleic Acids

SLNs can be used for the delivery of nucleic acids, such as: Small interfering RNA (siRNA) [40], Plasmid DNA [41], Antisense oligonucleotides [42].

Vitamins and Nutraceuticals

SLNs can encapsulate various vitamins and nutraceuticals, including: Vitamin D [43], Coenzyme Q10 (CoQ10) [44].

Cosmetics: SLNs can also be used in cosmetic formulations to encapsulate cosmetic actives for skin care products, hair care products, and more [45].

SLN encapsulate Herbal formulations

Solid lipid nanoparticles have been used to encapsulate various herbal extracts for improved delivery and bioavailability. Here is a list of some herbal extracts that have been loaded into SLNs:

1. **Curcumin:** Curcumin, the active compound in turmeric, has been encapsulated in SLNs to enhance its stability and bioavailability [46].
2. **Resveratrol:** Resveratrol, found in grapes is known for its antioxidant properties and has been loaded into SLNs for better delivery [34].
3. **Quercetin:** Quercetin, a flavonoid present in various fruits and vegetables, has been incorporated into SLNs to improve its solubility and absorption [47].
4. **Ginkgo biloba:** Extracts from Ginkgo biloba leaves, which are used for cognitive health, have been encapsulated in SLNs for controlled release [48].
5. **Ginseng Extract:** Ginsenosides from ginseng, known for their adaptogenic properties, have been encapsulated in SLNs for enhanced bioavailability [49].
6. **Milk Thistle Extract:** Silymarin, extracted from milk thistle seeds and used for liver health, has been loaded into SLNs for improved delivery [50].
7. **Aloe Vera Extract:** Aloe vera gel extracts have been incorporated into SLNs for topical applications, such as skincare products [51].
8. **Ashwagandha Extract:** Withanolides from ashwagandha, an adaptogenic herb, have been encapsulated in SLNs for improved bioavailability [52].
9. **Ginger Extract:** Gingerol compounds from ginger have been loaded into SLNs for controlled release and targeted delivery [53].
10. **Bilberry Extract:** Anthocyanins from bilberry, used for eye health, have been encapsulated in SLNs for improved stability [54].
11. **Echinacea Extract:** Active compounds from Echinacea plants, known for their immune-boosting properties, have been incorporated into SLNs [55].
12. **Garlic Extract:** Allicin, the active compound in garlic, has been loaded into SLNs for improved delivery and reduced odour [56].
13. **Saw Palmetto Extract:** Extracts from saw palmetto berries, used for prostate health, have been encapsulated in SLNs [57].





DISCUSSION

Solid lipid nanoparticles offer a promising platform for the encapsulation and delivery of Pharmaceutical and herbal extracts, enhancing their stability, bioavailability, and therapeutic efficacy. The encapsulation of various herbal compounds within SLNs has been extensively explored, demonstrating the versatility and potential of this drug delivery system.

Enhanced Stability and Bioavailability:

Encapsulation of herbal extracts such as curcumin, resveratrol, and quercetin in SLNs has been shown to improve their stability and bioavailability. This is crucial for maximizing the therapeutic effects of these compounds, which are often limited by poor solubility and low absorption rates.

Controlled Release and Targeted Delivery:

SLNs offer the advantage of controlled release, allowing for sustained delivery of herbal compounds over time. Additionally, the ability to modify SLNs with targeting ligands enables the selective delivery of these compounds to specific tissues or cells, enhancing therapeutic outcomes while minimizing side effects. For example, ginger has been encapsulated in SLNs to achieve controlled and targeted drug delivery.

Diverse Applications:

The encapsulation of herbal extracts in SLNs has enabled diverse applications, ranging from oral supplements to topical formulations. For example, SLNs loaded with aloe vera gel extracts have been used in skincare products for their moisturizing and anti-inflammatory properties, while SLNs containing adaptogenic herbs like ashwagandha have been explored for stress management and cognitive health.

Potential Synergistic Effects:

Combining multiple herbal extracts within SLNs may lead to synergistic effects, enhancing the overall therapeutic potential of the formulation. For instance, formulations containing ginseng and ginkgo biloba extracts could synergistically improve cognitive function and memory retention.

CONCLUSION

Solid lipid nanoparticles represent a transformative approach in the delivery of several of pharmaceutical formulations offering solutions to the longstanding issues of poor solubility, stability, and bioavailability. The advantages of SLN technology enhanced bioavailability, controlled release, improved stability, biocompatibility, targeted delivery, and enhanced therapeutic efficacy make it a valuable tool in the development of effective formulations. With ongoing advancements in preparation techniques and a growing understanding of their interactions with biological systems, SLNs hold immense potential to enhance the efficacy of synthetic and herbal medicines by expand their therapeutic applications. Future research and development efforts should aim at overcoming the current challenges and exploring new frontiers in SLN technology for herbal product delivery.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the review of this article.





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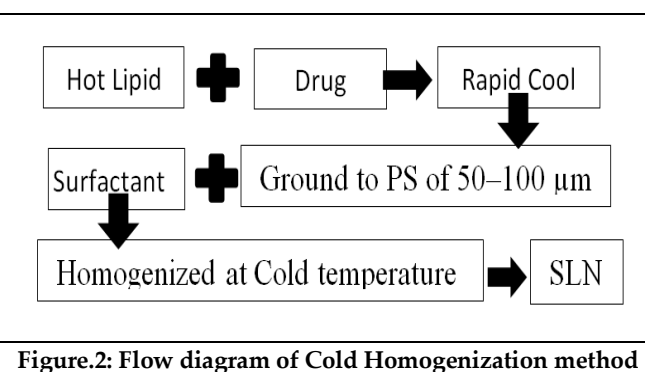
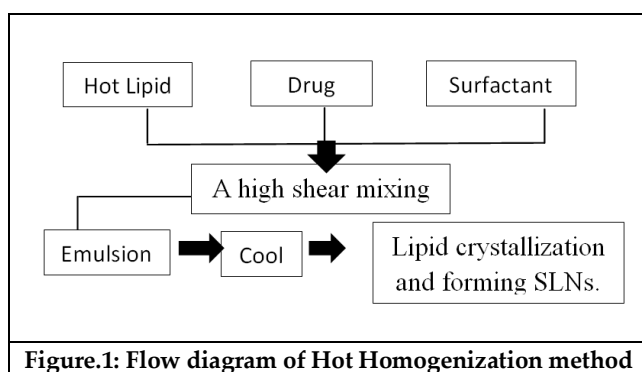
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Impact of Energy Consumption and Reduction Possibility in Rural Households of Madurai

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ABSTRACT

This research aims to investigate the energy consumption patterns and the economic impact of cooking fuel usage in rural households of Madurai district. The study will assess the current status of lighting equipment and the penetration of electrical appliances in these households. By analyzing the factors influencing energy consumption and the economic burden associated with cooking fuel, the research seeks to identify potential strategies for energy efficiency and sustainable energy solutions. The findings will contribute to developing targeted interventions to reduce energy consumption, improve household finances, and promote environmental sustainability in rural Madurai.

Keywords: Rural Energy Consumption, Energy Efficiency, Cooking Fuel, Economic Impact, Sustainable Energy.

INTRODUCTION

Energy, the lifeblood of modern civilization, is essential for driving economic growth, improving living standards, and powering technological advancements. It is the capacity to perform work, whether in the form of radiation, heat, or motion. While humanity cannot create energy, we can harness and transform it from one form to another. However, this transformation is contingent upon the presence of matter. Energy, a fundamental resource, is indispensable for various human activities, including heating, cooling, lighting, cooking, industrial production, and transportation. It has become an integral part of daily life and plays a crucial role in the social and economic progress of nations. Despite its significance, the environmental, social, and economic impacts of energy consumption are often





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overlooked. Energy consumption, particularly in rural areas, has increased significantly with the growing reliance on energy-intensive appliances and devices. Rural households in Madurai, like many other regions, face substantial energy expenditure. This research aims to investigate the impact of energy consumption on these households, quantifying the economic burden associated with different energy uses. By understanding the current energy consumption patterns, we can identify potential areas for reduction and explore strategies to promote energy efficiency and sustainability in rural communities.

Review of Literature

Kablan's (2004) study utilized the Analytic Hierarchy Process (AHP) to prioritize energy conservation policy instruments in Jordan. The findings suggest that Regulation and Legislation (RL) is the most promising policy, followed by Fiscal and Financial Incentives (FFI), Pricing Policy (PP), and Training, Education, and Qualification (TEQ). RL was prioritized due to its potential to compel energy-intensive entities to adopt efficient practices. FFI was seen as a motivator for implementing energy conservation programs. While PP can rationalize energy use, it may negatively impact certain industries. TEQ, although beneficial, might not be fully utilized without strong incentives or regulations. R&D was ranked lowest due to resource constraints. Rajmohan and Weerahewa (2007) examined household energy consumption patterns across urban, rural, and estate sectors in Sri Lanka over time and income groups. The study tested the energy ladder hypothesis and estimated Engel functions using consumer finance and socioeconomic survey data from 1978-79 to 2003-04. The findings revealed that the energy ladder hypothesis holds true for Sri Lanka, indicating a shift towards modern fuels like LPG and electricity. Urban areas demonstrated a faster transition compared to rural areas. Budget elasticity analysis showed negative values for firewood and kerosene in urban and estate sectors, classifying them as inferior goods. Conversely, LPG and electricity exhibited positive budget elasticities, indicating their status as normal goods.

Objective

- To evaluate the penetration of electrical appliances in rural households.
- To assess the current status of lighting equipment usage in rural households.
- To analyse the Economic Impact of Cooking Fuel Consumption in Rural Areas.

METHODOLOGY

To understand current energy consumption patterns and identify key factors influencing them, a combination of primary and secondary data was utilized. The purpose and need for the study were explained to respondents to build trust and encourage their participation in providing necessary information. Personal interviews and unbiased observations were employed as the most suitable methods to establish rapport with respondents and collect the required data. Secondary data, such as the number of households in the study area, was obtained from the District Statistical Handbook of Madurai District. To calculate energy consumption in kWh the following formulae is used

$$\text{Energy Consumption by kWh} = \frac{\text{Number of Equipments} \times \text{Hours Usage} \times \text{Watts per Equipment}}{1000}$$

RESULTS AND DISCUSSION

This section delves into the economic impact of electrical appliance usage, lighting equipment, and cooking fuel consumption in rural households within the Madurai district. Table 1 presents the types of home appliances employed by households in the study area, along with their corresponding electricity consumption in both real and monetary terms. This table aims to assess the penetration of electrical appliances in rural households. It is understood from Table 1 that the electricity consumed by the 320 rural households using different home appliances is 742.10 units per day. Of this, the major share is taken by fans and TVs. Fans consume 262.15 units of electricity per day, while TVs consume 196.24 units. Next come grinders (64.15 units) and mixers (56.45 units). It is estimated that the



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amount spent per day on home appliances by the selected rural households is Rs. 1110.15, which translates to an annual expenditure of Rs. 405,204.75. This part discusses how the increased use of electrical equipment leads to higher electricity consumption. Table 2 presents the types of lighting equipment used by rural households in the study area and the corresponding energy consumption in both real and monetary terms. It is observed from Table 2 that, in the rural areas per day electricity consumption for lighting purposes alone by using different equipments is estimated as 234.99 units. Out of these 139.45 units are due to using incandescent lamps and 86.24 units are by using tube lights. The usage of CFLs and LED bulbs are lesser in rural areas. By monetary terms, 320 rural households using different lighting equipment consume Rs. 345.81 worth of electricity per day. This translates to a bi-monthly expenditure of Rs. 20,780.25 (per reading). Annually, these rural households spend Rs. 124,681.01 on electricity for lighting purposes. Given that most rural households rely on incandescent lamps and tube lights, which are less energy-efficient, this contributes to higher electricity consumption. To mitigate this issue, it is imperative to encourage the adoption of CFLs and LEDs, which can significantly reduce electricity consumption in both real and monetary terms. To determine the differences in cooking fuel needs between rural and urban households, the researcher aimed to identify and estimate these needs in both real and monetary terms. The results are presented in Table 3. It is evident from Table 3 that the major types of fuel consumed by the rural households for cooking is firewood and agricultural residue/waste, kerosene and LPG. Among these three, the usage of firewood and agricultural residue/waste plays a vital role. The majority of the rural people use firewood and agricultural residue/waste as cooking fuel. It is due to easy availability and low cost and sometimes free of cost. But they don't have the knowledge of internal smoke and its ill effects. The per day consumption of firewood and agricultural residue/waste is 549.61 kg. If we convert the value into monetary term, it is Rs. 2686.00 per day, Rs.161160.00 per month and Rs.980390 per year. The next dominant fuel used by the households for cooking is kerosene. The rural households use 72.61 litre of kerosene and its value is Rs.993.85 per day. Annually the rural households spent Rs.362755.25 for kerosene. For kerosene the people depend on ration shops because the price of kerosene in the open market is very high. LPG consumption in the rural area is low. The LPG consumption made for cooking purpose is 26.35 kg. per day. The money spent on it per day is Rs.1342.16 and per annum is Rs.49888.40 and so for cooking alone the rural sample households spent Rs.1833033.65 per annum totally.

CONCLUSION

The research undertaken to assess the energy consumption patterns and economic impact in rural households of Madurai district has yielded valuable insights. The study highlights the significant reliance on traditional fuels like firewood and agricultural residues, along with increasing dependence on electricity for lighting and appliance usage. The analysis revealed that a substantial portion of household expenditure is directed towards energy consumption, particularly for cooking and lighting purposes. This economic burden underscores the need for efficient energy utilization and the exploration of alternative, sustainable energy sources. The study has identified key factors influencing energy consumption patterns, including household size, income levels, and access to modern energy services. The findings emphasize the potential for energy efficiency improvements through the adoption of energy-efficient technologies, such as LED lighting, energy-efficient appliances, and improved cookstoves.

To promote sustainable energy practices, the following recommendations are proposed:

1. Policy Interventions:

- Implement supportive policies and incentives to promote the adoption of renewable energy technologies.
- Strengthen the rural electrification program to ensure reliable and affordable electricity access.
- Enact stringent regulations to control the use of polluting fuels and promote clean energy alternatives.

2. Awareness and Capacity Building:

- Conduct awareness campaigns to educate rural households about energy conservation and efficient energy use.
- Organize training programs to empower households to make informed decisions about energy choices.
- Facilitate skill development in the installation and maintenance of renewable energy systems.





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3. Financial Support

○ Provide subsidies and concessional loans to encourage the adoption of energy-efficient technologies and renewable energy systems.

○ Establish microfinance schemes to enable rural households to invest in energy-saving measures.

By implementing these recommendations, it is possible to reduce energy consumption, mitigate environmental impacts, and improve the overall well-being of rural households in Madurai district. Continued research and monitoring are essential to assess the effectiveness of these interventions and to adapt strategies to evolving needs and technological advancements.

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Table.1: To evaluate the penetration of electrical appliances in rural households

Sl. No.	Equipments	Units Consumed	Expenditure (in Rs.)		
			Expenditure Per Day	Bi – Monthly	Per Year
1.	Fan	262.15	396.24	23774.40	144627.60
2.	TV	196.24	298.21	17892.60	108846.65
3.	Radio	1.76	2.65	159.00	967.25
4.	Iron Box	44.24	66.24	3974.40	24177.60
5.	Mixie	56.45	84.15	5049.00	30714.75
6.	Grinder	64.15	96.22	5773.20	35120.30
7.	Refrigerator	55.00	82.00	4920.00	29930.00
8.	Washing Machine	1.14	1.68	100.80	613.20
9.	Heater	13.62	19.22	1153.20	7015.30
10.	AC	11.24	19.20	1152.00	7008.00
11.	Computer	34.15	48.15	2889.00	17574.75
12.	Electric Stove	1.96	2.49	--	908.85
	Total	742.10	1110.15	66699.80	405204.75

Source: Survey Data.





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Table.2: Economic Impact by Lighting Equipments in Rural

Sl. No.	Equipments	Units Consumed	Expenditure (in Rs.)		
			Per Day	Bi- Monthly	Per Year
1.	Tube Lights	86.24	126.15	7588.24	45491.24
2.	CFLs	9.24	13.45	762.13	4532.00
3.	Incandescent	139.45	206.14	12426.26	74635.14
4.	LEDs	0.06	0.07	3.62	22.63
	Total	234.99	345.81	20780.25	124681.01

Source: Survey Data.

Table.3 : Economic Impact By Cooking Fuel Consumption In Rural Areas

Sl. No.	Fuel Type	Units	Consumption	Expenditure (in Rs.)		
				Per Day	Bi – Monthly	Per Year
1.	Firewood and Agricultural Residue/Waste	KG	549.61	2686.00	161160.00	980390.00
2.	Kerosene	Litre	72.61	993.85	59631.00	362755.25
3.	LPG	KG	26.35	1342.16	80529.60	489888.40
	Total			5022.01	301320.60	1833033.65

Source: Survey Data.





A Comprehensive Pharmacognostic and Pharmacological Review of *Colocasia esculenta* (L) Schott

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ABSTRACT

The annual herbaceous plant *Colocasia esculenta* (L) Schott (Family: Araceae) has an extended past of utilization in old-style medication in many nations, particularly in tropical and subtropical areas. Aravi, Alukam, Kesavedantu, and Chamadumpa are some of its Indian names. The traditional Indian food system uses the plant's corm and leaves extensively as vegetables. The herb's medicinal properties, known since antiquity, have been utilised to treat numerous disorders like asthma, internal haemorrhages, arthritis, diarrhoea, nervous diseases, and issues with skin. Baldness and bodily aches are two common conditions treated with the juice of the *Colocasia esculenta* corm. The delicate roots and leaves are rich in vitamin C and carbohydrates. The components of this material are flavones, calcium, phosphorus, thiamine, riboflavin, niacin, lutein, apigenin, sapotoxin, and calcium oxalate. Phytochemical analysis also confirms the presence of alkaloids, saponins, terpenoids, oxalates, glycosides, phenols and flavonoids. *Colocasia esculenta* extracts include the pharmacologically active phytochemicals, flavonoids and triterpenoids, which are present in the plant's leaves and stems. This study focuses on the current phytopharmacological profile of *Colocasia esculenta* (L.) Schott. It includes antihepatotoxic, antimicrobial, antioxidant, antibacterial, anti-cancer, antifungal, hypolipidemic, anthelmintic, anti-inflammatory, and neuropharmacological properties. Future research should concentrate on *Colocasia esculenta* (L) Schott pharmacological properties, phytochemistry, clinical trials, and pharmacokinetics to maximise the species' therapeutic potential. To ensure that *Colocasia esculenta* has a viable clinical application, it will provide comprehensive knowledge of the plant.





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Keywords: *Colocasia esculenta* (CE) Linn, Araceae, phytopharmacological profile, clinical trials, pharmacokinetics.

INTRODUCTION

Plants are very important for human survival. All plant species, including ferns, seed plants, bryophytes, and mosses, that produce significant antibodies. Herbs have been used since the beginning of human civilization. India's vast forests are the rich natural resources provided to it. Natural medicine should be important for treatment, especially in rural areas of India.[1] Many of today's medicines are derived from these natural sources, many of which are named after the atmospheric environment. In order to prevent and treat various illnesses, almost 80% of people on the planet still only use traditional medicine. Medicinal herbs and extracts may cure liver, heart, nervous system, gastrointestinal tract, and metabolic disorders due to their various biological qualities. Numerous biological activities have been demonstrated by medicinal plants, herbs, and their preparations, including single molecules.[2] Taro is a multipurpose plant. This plant is mostly produced for its edible bulbs, which are a type of root vegetable also called taro.[3] Taro is a recurrent herbaceous wetland herb native to Asia, primarily found in tropical and subtropical climates. It goes by several names, including Arbi, Arvi, and Eddode. Taro is one of the main crops of the subfamily Araceae, also known as Aroideae.[4] Over 9,000 years ago, taro was cultivated.[5] This ancient crop from Southeast Asia is now an important crop throughout the Caribbean, Africa, Asia, and the Pacific.[6] Root crops like taro provide the majority of income for 500 million people, or 10% of the world's population.[7] Rice, cassava, sweet potatoes, and potatoes are less nutrient-dense than taro. Rubefacient and stimulating qualities can be found in the plant's leaf juice. Adenitis, haemorrhages, boils, and internal otalgia can also be treated with it [8]. Studies have indicated that taro leaves are a good source of calcium, phosphorus, iron, niacin, riboflavin, and thiamine. Edible fresh leaves of taro are rich in essential nutrients, dietary fibre, protein, and ascorbic acid [9]. This kind is more prevalent in Japan and China. Around the world, this plant may thrive in a range of settings, from flood plains to tropical rainforests. Taro, the world's ninth-most common food crop, originated in India. [10]

PROFILE OF PLANT

There are two other names for *Colocasia esculenta* Linn. (Family: Araceae): "*Arum esculentum* Linn" and "*Colocasia antiquorum* Schott.[11] Major root crop *Colocasia esculenta* Linn Schott is a member of the Araceae family, specifically the Aroideae subfamily.[12] Taro is an underground stem and monocotyledonous plant.[13] Taro is an herbaceous plant that reaches a height of one to two meters. The bottom part of the plant bears leaves, while the centre corm of the plant is located just below the soil's surface.[14]

Vernacular Names [15,16]

Marathi: Alu

Gujarati: Alavi, Patarveliya

Kannada: Kesavedantu

Malayalam: Chempu, Madantha, Chempakizhanna

Hindi: Arvi, Kachalu

English: Taro

Sanskrit: Alupam, Alukam

Tamil: Sempu

Bengali: Alti Kachu, Kachu

MORPHOLOGY

The herbaceous perennial *Colocasia esculenta* (L) Schott is known by the common name's cocoa and taro and is a tall herb that either has a robust, short caudex that concurrently bears flowers and leaves, or it is tuberous. The morphological characteristics of taro, including its corm, stolon, leaf, petiole, and flora, as well as other quantitative



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traits, can be used to describe the plant. According to Lebot et al. (2016), taro accessions from Southeast Asia and Oceania exhibited a high degree of morphological diversity.[17] The lamina peltate is either ovate-cordate or sagittate-cordate, and the simple leaves feature a thick petiole. Both the spadix and the appendix are significantly shorter than the petiole and inflorescence, respectively. The petiole is 15–35 centimetres shorter than the spathe and has a pale-yellow spathe, an oval-shaped, greenish tube, and a widely lanceolate, acuminate, convolute lamina that rarely expands extensively and curls slightly backwards while in bloom. Male inflorescences are tall and cylindrical, whereas female ones are tiny. Neuters are generally between them. Appendix: upright, subulate, abbreviate, elongate-conical, or fusiform. Male flowers are three to six-anded. Male inflorescence is long and cylindrical, and it typically stands in between the two female inflorescences, which are short. Female flowers have 3–4 gynous. Sulcate the oblong seeds. much albumen; embryo axile. An above-ground plant stem that is somewhat inflated at the base of the leaf sheaths emerges from a firm, tapered rhizome. Occasionally, stolons and suckers from tuberous rhizomes may be observed. Compared to the fertile zones, the sterile floral zone and the distal appendage are shorter. Fruit is a berry that has a fruiting cap made up of several densely packed seeds. Less than 2 mm long and ovoid to ellipsoid in shape, seeds have an abundance of endosperm. [18,19]

ETHNOMEDICAL USES

The whole plant has antibacterial, antifungal, hepatoprotective, hypoglycaemic, anti-lipid peroxidation, and anti-inflammatory properties. Leaf juice is utilised as a stimulant, appetizer, expectorant, otalgia, and astringent, as well as to maintain healthy mucous membranes, skin, and vision [19]. It is also used as a cancer remedy for the mouth and lungs. The leaf juice's hydroalcoholic extract has sedative, antidepressant, anxiolytic, and smooth muscle relaxant properties. Body pains and external baldness are treated with corm juice. It has internal uses as a laxative, anodyne, demulcent, and galactagogue. It is applied to pile treatment [20].

PHYTOCHEMISTRY

Flavonoids and triterpenoids dominate *Colocasia esculenta* leaf extracts' pharmacological activity. Leaf phytochemistry of *Colocasia esculenta* shows flavones, luteolin, apigenin, and anthocyanins [21]. *Colocasia esculenta* tubers contain 80% globulins. Taro corms contain 70–80% starch with small granules (dry weight basis). The tubers contain 1,380 to 2,397 mg/100g of amino acids, and raw and powdered taro are heavy in carbs [22]. "Alkaloids", "flavonoids", "glycosides", "phenols", "saponins", "steroids", and "tannins" were in *Colocasia esculenta* stem extract. Steroids, glycosides, and flavonoids were weakly detectable. Despite uncommon alkaloids, phenols, and saponins, tannins predominated. The *Colocasia esculenta* leaf flavonoid were extracted by Iwashina et al. UV spectral analysis found flavonoids. "Vicenin-2", "vitexin X"-O-glucoside, "luteolin 7-O-glucoside", "isoorientin", "isovitexin", and "orientin 7-O-glucoside" were the eight flavonoids [23].

REPORTED PHARMACOLOGIC ACTIONS

Hypoglycaemic action

The ethanol extract of *Colocasia esculenta* leaves has antidiabetic properties in an alloxan-induced diabetes mouse. To compare alloxan (120 mg/kg, i.p.)-induced diabetic rats with metformin 450 mg/kg, *Colocasia esculenta* ethanol extract was given orally at 100, 200, and 400 mg/kg. A hypoglycaemic impact from EECE peaked at 6 hours (120 mg/dl) but diminished after 24 hours. Blood glucose dropped at 4 hours (96 mg/dl). At 400 mg/kg on the 14th day of the subacute investigation, blood glucose decreased the greatest (174.34 mg/dl). EECE ceased weight loss. In rats with alloxan-induced diabetes, EECE (400 mg/kg) showed significant anti-hypoglycaemic activity [24].

Antioxidant activity

Aqueous extracts of *Colocasia esculenta* corms showed powerful antioxidant in addition to free radical scavenging capabilities. The extract was evaluated using seven different assays, including antioxidant activity against nitric oxide (NO), DPPH, and ABTS radicals, total flavonoid and phenolic content, complete flavanol content, and reduction of power calculation. *Colocasia esculenta* corm's antioxidant potential was mainly attributed to its phytoconstituents, which included tannins, saponins, flavonoids, steroids, carbohydrates, proteins, and glycosides [25].





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Antimicrobial activity

Colocasia esculenta, also referred to as taro, is a highly beneficial medicinal plant that Charaka describes as having anti-inflammatory properties. Using the diffusion agar method, an investigation stood conducted to determine the antimicrobial action of the *Colocasia esculenta* plant's methanol and chloroform extract. In order to evaluate and compare the zone of inhibition caused by methanol extract and chloroform at doses of 20, 10, 5, 2.5, 1.25, 0.625, and 0.3125 mg/ml against specific strains, tetracycline at doses of 5, 2.5, 0.625, 0.3125, 0.15625, and 0.078072 mg/ml was used as a reference antibiotic [26].

Hepatoprotective activity

The study examined the hepatoprotective and antihepatotoxic properties of *Colocasia esculenta* leaf juice against the hepatotoxins paracetamol using the in vitro liver slice technique. Hepatocyte damage results from the free radicals that these substances produce, which also damage cell organelles and induce oxidative stress. In the presence of paracetamol and CCL₄, the leaf juice's marker enzyme levels increased, suggesting hepatotoxicity. The integrity of the hepatocyte was indicated by the significant reduction in AST, ALT, and ALP leakage caused by the leaf juice of *Colocasia esculenta*. Study results that support the hepatoprotective and antihepatotoxic properties of *Colocasia esculenta* leaf juice were examined in vitro utilizing a rat liver slice model.[27]

Anthelmintic activity

Earthworms were used as test subjects for the anthelmintic qualities of *Colocasia esculenta* leaf extracts, both ethanolic and aqueous. In the 10–50 mg/ml concentration range, both extracts demonstrated dose-dependent anthelmintic efficacy. In addition to causing paralysis, the crude extracts of *Colocasia esculenta* killed the worms, especially when the concentration was higher. Compared to the water extract of *Colocasia esculenta*, the ethanol extracts show more effective paralysis and death time against the earthworm.[28]

Anti-inflammatory activity

Albino Wistar rats with pleurisy, granules generated by cotton pellets, and left hind paw oedema induced by carrageenan were used to investigate the anti-inflammatory properties of an ethanolic extract derived from the leaves of *Colocasia esculenta* Linn. Ethanol extract (100 mg/kg, p.o.) reduced carrageenan-induced paw edema. Cotton pellets reduced pleural exudates, leukocyte migration and granulation weight. Ethanolic extract significantly decreased inflammatory response compared to normal and untreated groups of controls ($p < 0.05$).[29]

Anti-Cancer activity

A *Colocasia esculenta* leaf ethanolic extract was tested for cytotoxicity and apoptosis in Pa-1 ovarian carcinoma cell lines. The cytotoxic and apoptotic effects were measured using MTT assays. The extract of leaves showed the highest cytotoxicity at 93.2 µg/mL, acting dose-dependently. In contrast to cisplatin, which caused 41.76% and 46.42% a process called Annexin V and PI late and early cells that were apoptotic also died. Pa-1 ovarian cancer cells may be susceptible to the ethanol extract's cytotoxicity as a possible therapeutic principle.[30]

Neuropharmacological activity

Leaf extracts from *Colocasia esculenta* were tested for neuropharmacological action in adult Wistar albino rats. The enhanced plus maize (EPM) group had greater anxiolytic effects and more open arms in comparison to the control group. Additionally, in Porsolt forced swimming test, the extracts demonstrated a dose-dependent reduction in immobility time. At doses of 50 and 100 mg/kg, i.p. the extracts significantly reduced the duration necessary for thiopental to induce sleep. This suggests that there could be neuropharmacological qualities to the plant.[31]

Antifungal activity

Colocasia esculenta's in vitro antifungal activity against two distinct fungus species was evaluated using the food poisoning approach. More antifungal activity was shown by the alcoholic leaf extract of *Colocasia esculenta* than by the water extract. The two species of *Alternaria solani* and *Alternaria ricini* were both completely eradicated by an





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alcoholic extraction of 25% *Colocasia esculenta*. Only aqueous leaf extract, when used at high quantities, inhibited the growth of fungal infections.[32]

Hypolipidemic activity

The research examined how aqueous extracts of *Colocasia esculenta* corms impacted hyperlipidaemic rats fed 25% fructose and P-407. The extract was contrasted to fenofibrate, a prominent hypolipidemic medication, for 15 and 21 days at 200 and 300 mg/kg. Triglycerides, LDL cholesterol, and VLDL cholesterol decreased significantly. The extract's efficacy was comparable to fenofibrate, suggesting *Colocasia esculenta* might be used to produce hypolipidemic drugs for the treatment of hyperlipidaemia and cardiovascular diseases.[34]

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Table 1: Taxonomical classification of *Colocasia esculenta*(L) Schott plant

Rank	Scientific Name
Kingdom	Plantae (Plants)
Subkingdom	Tracheobionta (Vascular plants)
Super division	Spermatophytes (Seed plants)
Division	Magnoliophyta (Flowering plants)
Class	Liliopsida (Monocotyledons)
Subclass	Arecidae
Order	Arales
Family	Araceae (Arum family)
Genus	<i>Colocasia</i> Schott (colocasia)
Species	<i>Colocasia esculenta</i> (L.) Schott (Coco yam)





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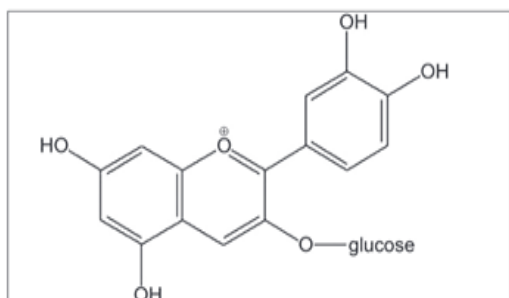
Figure 1: *Colocasia esculenta* (L) Schott PlantFigure 2: Various Parts of *Colocasia esculenta*(L) Schott plant

Figure 3: Anthocyanin

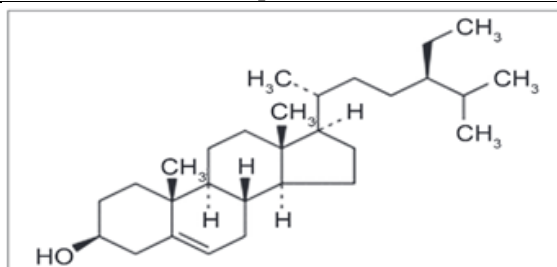
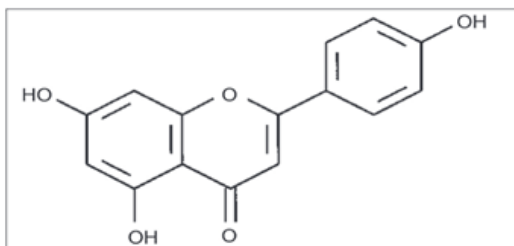
Figure 4: β - Sitosterol

Figure 5: Apigenin

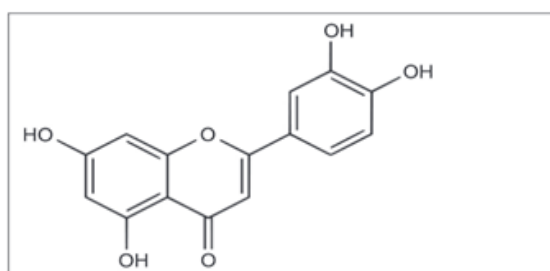
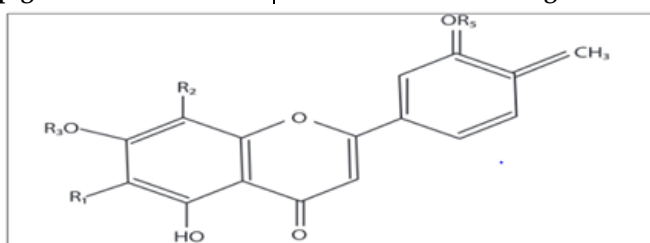


Figure 6: Luteolin

Figure 7: Structure of flavonoids isolated from *Colocasia esculenta* (L) Stems and leaves.



A Study on Fermatean Picture Fuzzy Graph

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ABSTRACT

In this paper, a new approach of Fermatean picture fuzzy graph along with some of basic properties is introduced. The fermatean picture fuzzy graph, subgraph, regular graph, complete graph are defined and examples are given. A natural life problem with an effective algorithm to solve problem and examples are given.

Keywords: Fermatean picture fuzzy graph, Fermatean picture fuzzy subgraph, Fermatean regular picture fuzzy graph, Fermatean strong picture fuzzy graph, Fermatean complete picture fuzzy graph.

INTRODUCTION

In 1965, L.A.Zadeh introduced the idea of fuzzy sets [1] which gives the membership of an object in a given set. Zimmerman H.J., [3] developed Fuzzy Set Theory and its Applications. Intuitionist fuzzy graph and some of its basic properties were introduced by Dipesh Chakravarthy and Nirmal Kumar Mahapatra [2]. Definitions, theorems and examples of Complete fuzzy graph was introduced Talal AL- Hawary [4]. Tapan Senapati, Ronald R Yager, proposed Fermatean Fuzzy Sets [5]. S.Sangeetha, dealt with regular graph, complete graph and its applications [6]. Arjunan K and Subramani.C, [7] extended of Notes on Fuzzy Graph. Parvathy R and Karunambigai M.G, introduced the new definitions and examples Intuitionistic Fuzzy Graphs [8], Nagoor Gani, A. and Radha, K., On Regular Fuzzy Graphs [9].





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S.Vijayalakshmi, S.Geetha, S.SahayaArockia Selvi, Complete Intuitionistic Fuzzy Graphs[10]. Nagoor Gani. A and Shajitha Begum.S,[11] Degree of a vertex, effective degree, neighbourgood degree, regular fuzzy graph, degree, order and size in intuitionistic fuzzy graphs,complete intuitionistic fuzzy graphs. S.Memis, some definitions and examples, properties of picture fuzzy sets[12].Assia Bakali.Mohamad Talia Said Broumi, R.Sundareswaran, M.Shanmugapriya,was introduced pythagorian fuzzy graph,Fermatean fuzzy gaph, Fermatean neutrosophic graphs, degree, size of Fermatean neutrosophic graphs definitions and examples[13].K.Lalitha and N.Buvaneswari, Some new results on Fermatean Fuzzy Sets using Implication[14], B.C.Coung, has put forward the concept of Picture Fuzzy Sets[15].In the Fermatean picture fuzzy sets ,the membership, neutral membership, non membership degrees are denoted by $\mu(x), \eta(x), \gamma(x)$ respectively.

Definition: 1.1

Let $G^* = (V, E)$ be a graph. A pair $G = (A, B)$ is called a fermatean picture fuzzy graph on G^* where $A = (\mu_{FPG1}, \eta_{FPG1}, \gamma_{FPG1})$ is a Fermatean Picture Fuzzy set on V and $B = (\mu_{FPG2}, \eta_{FPG2}, \gamma_{FPG2})$ is a Fermatean Picture Fuzzy set on $E \subseteq V \times V$ such that for each $uv \in E$.

$$\mu_{FPG2}(u, v) \leq \min \{ \mu_{FPG1}(u), \mu_{FPG1}(v) \}, \eta_{FPG2}(u, v) \leq \min \{ \eta_{FPG1}(u), \eta_{FPG1}(v) \}$$

$$\gamma_{FPG2}(u, v) \geq \max \{ \gamma_{FPG1}(u), \gamma_{FPG1}(v) \}.$$

Example

$$u(0.5, 0.6, 0.7) \quad (0.3, 0.5, 0.8) \quad (0.4, 0.55, 0.8) \quad v(0.4, 0.5, 0.8) \quad (0.4, 0.4, 0.85) \quad w(0.8, 0.8, 0.4)$$

Definition: 1.2

A Fermatean Picture Fuzzy graph $G = (A, B)$ is said to be Fermatean regular picture fuzzy graph if

$$\sum_{u \neq v} \mu_{FPG2}(u, v) = \text{Constant},$$

Example:

Figure.1 is also an example of Fermatean regular picture fuzzy graph.

Definition: 1.3

A Fermatean picture fuzzy graph $G = (A, B)$ is defined as Fermatean strong picture fuzzy graph is

$$\mu_{FPG2}(u, v) = \mu_{FPG1}(u) \wedge \mu_{FPG1}(v),$$

$$\eta_{FPG2}(u, v) = \eta_{FPG1}(u) \wedge \eta_{FPG1}(v),$$

$$\gamma_{FPG2}(u, v) = \gamma_{FPG1}(u) \wedge \gamma_{FPG1}(v).$$

Example:

$$X(0.5, 0.2, 0.5) \quad (0.2, 0.3, 0.5) \quad W(0.3, 0.5, 0.2)$$

$$U(0.8, 0.4, 0.2) \quad (0.3, 0.4, 0.2) \quad V(0.6, 0.6, 0.2)$$

Theorem: 1.4

Let $G = (A, B)$ be an Fermatean picture fuzzy graph with respect to the sets V and E . Let α_1, γ_1 and $\beta_1 \in [0, 1]$ and $\alpha \leq \alpha_1, \gamma \leq \gamma_1$, and $\beta \geq \beta_1$. Then $(A_{(\alpha_1, \gamma_1, \beta_1)}, B_{\alpha_1, \gamma_1, \beta_1})$ is an Fermatean Picture Fuzzy subgraph of $(A_{(\alpha, \gamma, \beta)}, B_{\alpha, \gamma, \beta})$.

Proof

G is a Fermatean Picture Fuzzy graph with respect to the sets V and E . Then for α_1, γ_1 and $\beta_1 \in [0, 1]$, $\alpha \leq \alpha_1, \gamma \leq \gamma_1$ and $\beta \geq \beta_1$ be given

$$\text{Now let } (x, \mu_{FPG1}(x), \eta_{FPG1}(x), \gamma_{FPG1}(x)) \in A_{(\alpha_1, \gamma_1, \beta_1)}.$$

$$\Rightarrow \mu_{FPG1}(x) \geq \alpha_1, \eta_{FPG1}(x) \geq \gamma_1, \gamma_{FPG1}(x) \leq \beta_1.$$

$$\Rightarrow \mu_{FPG1}(x) \geq \alpha, \eta_{FPG1}(x) \geq \gamma, \gamma_{FPG1}(x) \leq \beta.$$

$$[\text{Because } \alpha \leq \alpha_1, \gamma \leq \gamma_1, \beta \geq \beta_1]$$

$$\Rightarrow (x, \mu_{FPG1}(x), \eta_{FPG1}(x), \gamma_{FPG1}(x)) \in A_{(\alpha, \gamma, \beta)}.$$

$$\text{Therefore, } A_{(\alpha_1, \gamma_1, \beta_1)} \subseteq A_{(\alpha, \gamma, \beta)}.$$





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Now, let $((x,y), \mu_{FPG1}(x,y), \eta_{FPG1}(x,y), \gamma_{FPG1}(x,y)) \in B_{(\alpha_1, \gamma_1, \beta_1)}$.

$\Rightarrow \mu_{FPG2}(x,y) \geq \alpha_1, \eta_{FPG2}(x,y) \geq \gamma_1$ and $\gamma_{FPG2}(x,y) \leq \beta_1$

$\Rightarrow \mu_{FPG2}(x,y) \geq \alpha, \eta_{FPG2}(x,y) \geq \gamma$ and $\gamma_{FPG2}(x,y) \leq \beta$, because

$[\alpha \leq \alpha_1, \gamma \leq \gamma_1, \beta \geq \beta_1]$

$\Rightarrow ((x,y), \mu_{FPG2}(x,y), \eta_{FPG2}(x,y), \gamma_{FPG2}(x,y)) \in B_{(\alpha, \gamma, \beta)}$.

Therefore, $B_{(\alpha_1, \gamma_1, \beta_1)} \subseteq B_{(\alpha, \gamma, \beta)}$.

Hence, $(A_{(\alpha_1, \gamma_1, \beta_1)}, B_{(\alpha_1, \gamma_1, \beta_1)})$ is a Fermatean Picture Fuzzy subgraph of $(A_{(\alpha, \gamma, \beta)}, B_{(\alpha, \gamma, \beta)})$.

Definition: 1.5

The Fermatean Picture Fuzzy graph $H=(C,D)$ is said to be Fermatean Picture fuzzy subgraph of $G=(A,B)$ if $C \subseteq A$ and $D \subseteq B$.

$v_1(0.6, 0.4, 0.2) \quad (0.5, 0.2, 0.3) \quad v_2(0.6, 0.4, 0.2)$

$v_4(0.7, 0.3, 0.4) \quad (0.4, 0.3, 0.4) \quad v_3(0.4, 0.6, 0.2)$

Fermatean Picture fuzzy graph of G.

$v_1(0.6, 0.4, 0.2) \quad v_2(0.5, 0.2, 0.3)$

$v_4(0.7, 0.3, 0.4) \quad (0.4, 0.3, 0.4) \quad v_3(0.4, 0.6, 0.2)$

Definition: 1.5

A Fermatean Picture fuzzy graph $G=(A,B)$ is defined as Fermatean Complete picture fuzzy graph if

$\mu_{FPG2}(U, V) = \eta_{FPG1}(U) \wedge \eta_{FPG1}(V)$,

$\eta_{FPG2}(U, V) = \eta_{FPG1}(U) \wedge \eta_{FPG1}(V), \gamma_{FPG2}(U, V) = \gamma_{FPG1}(U) \wedge \gamma_{FPG1}(V), U, V \in V$.

Note: Every Fermatean Complete picture fuzzy graph is a Fermatean strong picture fuzzy graph but not conversely.

Example:-

$X(0.5, 0.4, 0.2)(0.5, 0.4, 0.2) \quad w(0.6, 0.7, 0.2)$

$u(0.3, 0.5, 0.6)(0.3, 0.5, 0.6) \quad v(0.4, 0.5, 0.3)$

A fermatean complete picture fuzzy graph.

Theorem: 1.7

Let $H=(C, D)$ be an Fermatean picture fuzzy subgraph of $G=(A,B)$ and $\alpha, \gamma, \beta \in [0,1]$.

Then $H_{(\alpha, \gamma, \beta)}$ is an fermatean picture fuzzy subgroup of $G_{(\alpha, \gamma, \beta)}$.

Proof:

Let $H=(C, D)$ be an FBFSG of $G = (A, B)$ and $\alpha, \gamma, \beta \in [0, 1]$. Suppose $(x, \mu_c(x), \eta_c(x), \gamma_c(x)) \in C_{(\alpha, \gamma, \beta)}$.

$\Rightarrow \mu_c(x) \geq \alpha, \eta_c(x) \geq \gamma, \text{ and } \gamma_c(x) \leq \beta$

$\Rightarrow (x, \mu_c(x), \eta_c(x), \gamma_c(x)) \in A_{(\alpha, \gamma, \beta)}$

So $C_{(\alpha, \gamma, \beta)} \subseteq A_{(\alpha, \gamma, \beta)}$.

Again let, $((x,y), \mu_D(x,y), \eta_D(x,y), \gamma_D(x,y)) \in D_{(\alpha, \gamma, \beta)}$

Then $\mu_D(x,y) \geq \alpha, \eta_D(x,y) \geq \gamma, \gamma_D(x,y) \leq \beta$.

$((x,y), \mu_D(x,y), \eta_D(x,y), \gamma_D(x,y)) \in B_{(\alpha, \gamma, \beta)}, D_{(\alpha, \gamma, \beta)} \subseteq B_{(\alpha, \gamma, \beta)}$.

Hence $H_{(\alpha, \gamma, \beta)} = (C_{(\alpha, \gamma, \beta)}, D_{(\alpha, \gamma, \beta)})$ is an Fermatean picture fuzzy subgraph of $G_{(\alpha, \gamma, \beta)} = (A_{(\alpha, \gamma, \beta)}, B_{(\alpha, \gamma, \beta)})$.

Theorem: 1.8

Let $G=(A,B)$ be an Fermatean picture fuzzy graph with respect to the sets V and E . Let $\alpha, \gamma, \beta, \alpha_1, \gamma_1$ and $\beta_1 \in [0,1]$ and $\alpha \leq \alpha_1, \gamma \leq \gamma_1$ and $\beta \geq \beta_1$. then $(A(\alpha_1^+, \gamma_1^+, \beta_1^+), B(\alpha_1^+, \gamma_1^+, \beta_1^+))$ is an Fermatean picture fuzzy size graph of $(A(\alpha^+, \gamma^+, \beta^+), B(\alpha^+, \gamma^+, \beta^+))$.

Poof

G is an Fermatean picture fuzzy graph with respect to the sets V and E . Then for $\alpha, \gamma, \beta, \alpha_1, \gamma_1$ and $\beta_1 \in [0,1]$ and $\alpha \leq \alpha_1, \gamma \leq \gamma_1$ and $\beta \geq \beta_1$ be given





Now, Let $(x, \mu_A(x), \eta_A(x), \gamma_A(x)) \in A(\alpha_1^+, \gamma_1^+, \beta_1^+)$

$\Rightarrow \mu_A(x) > \alpha_1, \eta_A(x) > \gamma_1, \text{ and } \gamma_A(x) < \beta_1$

$\Rightarrow \mu_A(x) > \alpha_1 \geq \alpha, \eta_A(x) > \gamma_1 \geq \gamma, \gamma_A(x) < \beta_1 \leq \beta,$

$\Rightarrow (x, \mu_A(x), \eta_A(x), \gamma_A(x)) \in A(\alpha^+, \gamma^+, \beta^+)$

Therefore $A(\alpha_1^+, \gamma_1^+, \beta_1^+) \subseteq A(\alpha^+, \gamma^+, \beta^+)$.

Now, Let $((x,y), \mu_B(x,y), \eta_B(x,y), \gamma_B(x,y)) \in B(\alpha_1^+, \gamma_1^+, \beta_1^+)$.

$\Rightarrow \mu_B(x,y) > \alpha_1, \eta_B(x,y) > \gamma_1, \text{ and } \gamma_B(x,y) < \beta_1,$

$\Rightarrow \mu_B(x,y) > \alpha_1 \geq \alpha, \eta_B(x,y) > \gamma_1 \geq \gamma, \gamma_B(x,y) < \beta_1 \leq \beta,$

$\Rightarrow (x, \mu_B(x,y), \eta_B(x,y), \gamma_B(x,y)) \in B(\alpha^+, \gamma^+, \beta^+)$.

Therefore, $B(\alpha_1^+, \gamma_1^+, \beta_1^+) \subseteq B(\alpha^+, \gamma^+, \beta^+)$.

Hence $(A(\alpha_1^+, \gamma_1^+, \beta_1^+), B(\alpha_1^+, \gamma_1^+, \beta_1^+))$ is an Fermatean picture fuzzy size graph of $(A(\alpha^+, \gamma^+, \beta^+), B(\alpha^+, \gamma^+, \beta^+))$.

Theorem: 1.9

Let $H=(C, D)$ be an Fermatean picture fuzzy size graph of $G = (A, B)$ and $\alpha, \gamma, \beta \in [0,1]$. Then $H(\alpha^+, \gamma^+, \beta^+)$ is an Fermatean picture fuzzy size graph of $G(\alpha^+, \gamma^+, \beta^+)$.

Proof:

Let $H=(C,D)$ be an Fermatean picture fuzzy size graph of $G=(A,B)$ and $\alpha, \gamma, \beta \in [0,1]$. Suppose $(x, \mu_C(x), \eta_C(x), \gamma_C(x)) \in C(\alpha^+, \gamma^+, \beta^+)$.

$\mu_C(x) > \alpha, \eta_C(x) > \gamma, \gamma_C(x) < \beta.$

$(x, \mu_C(x), \eta_C(x), \gamma_C(x)) \in C(\alpha^+, \gamma^+, \beta^+)$.

$C(\alpha^+, \gamma^+, \beta^+) \subseteq A(\alpha^+, \gamma^+, \beta^+)$.

Again let, $((x,y), \mu_D(x,y), \eta_D(x,y), \gamma_D(x,y)) \in D(\alpha^+, \gamma^+, \beta^+)$.

$\mu_D(x,y) > \alpha, \eta_D(x,y) > \gamma, \gamma_D(x,y) < \beta.$

$((x,y), \mu_D(x,y), \eta_D(x,y), \gamma_D(x,y)) \in B(\alpha^+, \gamma^+, \beta^+)$.

$D(\alpha^+, \gamma^+, \beta^+) \subseteq B(\alpha^+, \gamma^+, \beta^+)$.

Hence $H(\alpha^+, \gamma^+, \beta^+) = (C(\alpha^+, \gamma^+, \beta^+), D(\alpha^+, \gamma^+, \beta^+))$

is an FPFSG of $G(\alpha^+, \gamma^+, \beta^+) = (A(\alpha^+, \gamma^+, \beta^+), B(\alpha^+, \gamma^+, \beta^+))$.

Definition: 1.10

Let $G=(A,B)$ be an Fermatean picture fuzzy graph with respect to the sets V and E . Then the degree of a vertex V is defined by $d(v) = (d_\mu(v), d_\eta(v), d_\gamma(v))$ where $d_\mu(v) = \sum_{u \neq v} \mu_2(v, u)$, $d_\eta(v) = \sum_{u \neq v} \eta_2(v, u)$, $d_\gamma(v) = \sum_{u \neq v} \gamma_2(v, u)$.

Definition: 1.11

The maximum degree of the FPFSG G is $\Delta(G) = (\Delta_\mu(v), \Delta_\eta(v), \Delta_\gamma(v))$ where $\Delta_\mu(G) = \bigvee \{d_\mu(v) : v \in V\}$, $\Delta_\eta(G) = \bigvee \{d_\eta(v) : v \in V\}$ and $\Delta_\gamma(G) = \bigvee \{d_\gamma(v) : v \in V\}$.

Definition: 1.12

The minimum degree of the FPFSG G is $\delta(G) = (\delta_\mu(v), \delta_\eta(v), \delta_\gamma(v))$ where $\delta_\mu(G) = \bigwedge \{d_\mu(v) : v \in V\}$, $\delta_\eta(G) = \bigwedge \{d_\eta(v) : v \in V\}$ and $\delta_\gamma(G) = \bigwedge \{d_\gamma(v) : v \in V\}$.

Definition: 1.13

Let $G=(A,B)$ be an Fermatean picture fuzzy graph then the order of FPFSG G is defined by $O(G) = (O_\mu(G), O_\eta(G), O_\gamma(G))$ where $O_\mu(G) = \sum_{v \in V} \mu_1(v)$, $O_\eta(G) = \sum_{v \in V} \eta_1(v)$, $O_\gamma(G) = \sum_{v \in V} \gamma_1(v)$.

Definition: 1.14

Let $G=(A,B)$ be an Fermatean picture fuzzy graph with respect to the sets V and E . Then the size FPFSG is defined by $S(G) = (S_\mu(G), S_\eta(G), S_\gamma(G))$ where $S_\mu(G) = \sum_{u \neq v} \mu_2(u, v)$, $S_\eta(G) = \sum_{u \neq v} \eta_2(u, v)$, $S_\gamma(G) = \sum_{u \neq v} \gamma_2(u, v)$.



**Theorem: 1.15**

Let $d(v)=(d_\mu(v), d_\eta(v), d_\gamma(v))$ be the degree of the vertex v of the FPFG $G=(A,B)$ and $S(G)=(S_\mu(G), S_\eta(G), S_\gamma(G))$ be its size, then $\sum_{vi \in V} d_{\mu_1}(v_i) = 2S_\mu(G)$, $\sum_{vi \in V} d_{\eta_1}(v_i) = 2S_\eta(G)$ and $\sum_{vi \in V} d_{\gamma_1}(v_i) = 2S_\gamma(G)$.

Proof

Let $G=(A,B)$ be an FPFG with respect to V and E , where $V=\{v_1, v_2, \dots, v_n\}$

Now, $d_\mu(v_i) = d_\mu(v_1) + d_\mu(v_2) + \dots + d_\mu(v_n)$,

$$= \mu_2(v_1, v_2) + \mu_2(v_1, v_3) + \mu_2(v_1, v_4) + \dots + \mu_2(v_1, v_n) + \dots + \mu_2(v_n, v_1) + \mu_2(v_n, v_2) + \dots + \mu_2(v_{n-1}, v_n),$$

$$= 2[\mu_2(v_1, v_2) + \mu_2(v_1, v_3) + \dots + \mu_2(v_1, v_n),$$

$$= 2\sum_{v_i \neq v_j} \mu_2(v_i, v_j),$$

$$= 2S_\mu(G).$$

$$\therefore \sum d_\mu(v_i) = 2S_\mu(G),$$

Similarly, we can prove

$$\therefore \sum d_\eta(v_i) = 2S_\eta(G),$$

$$\therefore \sum d_\gamma(v_i) = 2S_\gamma(G).$$

This completes the proof.

Example

Let us consider an FPFG G ,

For this FPFG G $d_\mu(v_1)=0.3, d_\mu(v_2)=0.3, d_\mu(v_3)=0.2, d_\mu(v_4)=0.4$ and $d_\eta(v_1)=0.3, d_\eta(v_2)=0.6, d_\eta(v_3)=0.4, d_\eta(v_4)=0.2$,

$d_\gamma(v_1)=1.4, d_\gamma(v_2)=2.2, d_\gamma(v_3)=1.5, d_\gamma(v_4)=2.5$.

So $\delta_\mu(G)=0.2, \delta_\eta(G)=0.2, \delta_\gamma(G)=1.4$,

$\Delta_\mu(G)=0.4, \Delta_\eta(G)=0.6, \Delta_\gamma(G)=2.5, S_\mu(G)=0.6, S_\eta(G)=0.4, S_\gamma(G)=3.8$.

Note:

$$0 \leq \delta_\mu(G) \leq \Delta_\mu(G), 0 \leq \delta_\eta(G) \leq \Delta_\eta(G), 0 \leq \delta_\gamma(G) \leq \Delta_\gamma(G).$$

Theorem: 1.16

Let G be any FPFG and P be the numbers of the Vertices. Then $\delta_\mu(G) \leq \frac{2S_\mu(G)}{p} \leq \Delta_\mu(G), \delta_\eta(G) \leq \frac{2S_\eta(G)}{p} \leq \Delta_\eta(G), \delta_\gamma(G) \leq \frac{2S_\gamma(G)}{p} \leq \Delta_\gamma(G)$.

Proof

Suppose $G=(A,B)$ be any FPFG and P be the number of vertices.

If every vertex has degree

$\delta(G)=(\delta_\mu(G), \delta_\eta(G), \delta_\gamma(G))$, then

$$\sum_{v \in V} d_\mu(v) = \sum_{v \in V} \delta_\mu(G) = P\delta_\mu(G),$$

$$\sum_{v \in V} d_\eta(v) = \sum_{v \in V} \delta_\eta(G) = P\delta_\eta(G) \text{ and}$$

$$\sum_{v \in V} d_\gamma(v) = \sum_{v \in V} \delta_\gamma(G) = P\delta_\gamma(G).$$

$\Delta(G)=(\Delta_\mu(G), \Delta_\eta(G), \Delta_\gamma(G))$ then,

$$\sum_{v \in V} d_\mu(v) = \sum_{v \in V} \Delta_\mu(G) = P\Delta_\mu(G),$$

$$\sum_{v \in V} d_\eta(v) = \sum_{v \in V} \Delta_\eta(G) = P\Delta_\eta(G) \text{ and}$$

$$\sum_{v \in V} d_\gamma(v) = \sum_{v \in V} \Delta_\gamma(G) = P\Delta_\gamma(G).$$

But, $\sum_{v \in V} \delta_\mu(G) \leq \sum_{v \in V} d_\mu(v) \leq \sum_{v \in V} \Delta_\mu(G)$;

$$\Rightarrow P\delta_\mu(G) \leq \sum_{v \in V} d_\mu(v) \leq P\Delta_\mu(G);$$

$$\text{ie, } \delta_\mu(G) \leq 2d_\mu(v) \leq \Delta_\mu(G),$$

Similarly $\delta_\eta(G) \leq 2d_\eta(v) \leq \Delta_\eta(G)$ and

$$\delta_\gamma(G) \leq 2d_\gamma(v) \leq \Delta_\gamma(G).$$



**Theorem: 1.16**

Let $G=(A,B)$ be an FPPG with respect to V and E with number of fuzzy vertices n , all of whose FPF vertices have degree (s_1, s_2, s_3) or (t_1, t_2, t_3) . If G has P vertices of degree (s_1, s_2, s_3) and $(n-p)$ vertices of degree (t_1, t_2, t_3) . Then $S_\mu(G) = \frac{P(s_1-t_1)+nt_1}{2}$, $S_\eta(G) = \frac{P(s_2-t_2)+nt_2}{2}$ and $S_\gamma(G) = \frac{P(s_3-t_3)+nt_3}{2}$.

Proof:

Let v_1 be the set of all fuzzy vertices with degree (s_1, s_2, s_3) and v_2 be the set of all vertices with degree (t_1, t_2, t_3) .

Then $\sum_{v \in V} d_\mu(v) = \sum_{v \in V_1} d_\mu(v) + \sum_{v \in V_2} d_\mu(v)$;

(or) $2S_\mu(G) = Ps_1 + (n-p)t_1$;

ie $S_\mu(G) = \frac{P(s_1-t_1)+nt_1}{2}$

Also $\sum_{v \in V} d_\eta(v) = \sum_{v \in V_1} d_\eta(v) + \sum_{v \in V_2} d_\eta(v)$;

$\sum_{v \in V} d_\gamma(v) = \sum_{v \in V_1} d_\gamma(v) + \sum_{v \in V_2} d_\gamma(v)$;

Or $2S_\eta(G) = Ps_2 + (n-p)t_2$;

$2S_\gamma(G) = Ps_3 + (n-p)t_3$;

$\therefore S_\mu(G) = \frac{P(s_1-t_1)+nt_1}{2}$

CONCLUSION

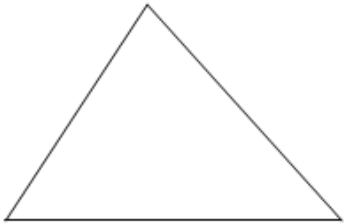

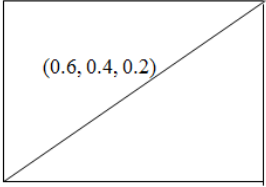

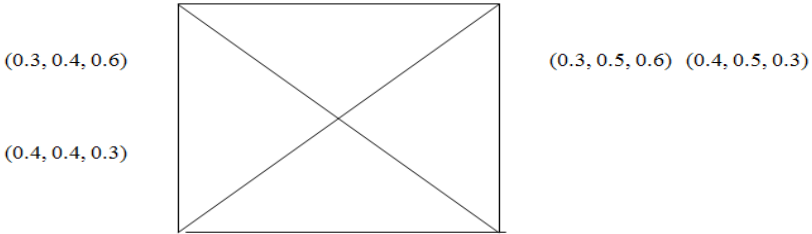
In this paper, the concept of fermatean picture fuzzy graph is introduced. The fermatean picture fuzzy graph, some new definitions, subgraph, regular graph, complete are defined and examples are given. A new approach of fermatean picture fuzzy graph some examples and properties established. A natural life problem with an effective algorithm to solve problem and examples are given. Further, order, degree, size, and total degree of FPPG are defined and some properties established.

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<p>Figure.1:A Fermatean Picture Fuzzy graphs.</p>	<p>Figure.2: A Fermatean strong picture fuzzy graph.</p>
	
<p>Figure.3: Fermatean Picture fuzzy graph of G.</p>	<p>Figure.4: A Fermatean Picture fuzzy graph G</p>
	
<p>Figure.5: A fermatean complete picture fuzzy graph002E</p>	





Effect of Static Stretching in Hamstring Muscle Flexibility of Patients with Mechanical Low Back Pain

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ABSTRACT

To determine if the flexibility of patients with mechanical low back pain will improve after 6-weeks of static stretching program. We also determine the pain and disability of the patients. We used pre-test post-test comparative experimental study design. A total sample of 29 participants with mean age of 30.37 with tight hamstring and mechanical low back pain participated in the study. They were treated for 30 seconds of intervention, 5 days in a week for six weeks. According to the results presented in the preceding section, there is a significant improvement in all three outcome measures: Oswestry scores, NPRS scores, and hamstring tightness for data collected between the first and sixth weeks. After the sixth week, treatment was discontinued, and a follow-up was performed at the eighth week. When the data from the sixth and eighth weeks were compared, it was found that there is an increase in all the three outcome measures. As a result, it was determined that hamstring stretching treatment protocol reduces patients' low back pain, assists them in minimising hamstring muscle tightness, and improves their functional ability this study shows that static stretching, is effective in increasing hamstring flexibility of patients with mechanical low back pain there is significant improvement seen in hamstring muscle flexibility along with reduction in low back pain and improvement in functional disability

Keywords: Static stretching, flexibility, Extensibility, Low back pain and injury prevention.





INTRODUCTION

Stretching is used as part of physical fitness and rehabilitation program because it is thought to positively influence performance and injury prevention. Numerous studies [1, 3, 5,] have been conducted to investigate the effectiveness of stretching. Shortness and contracture of hamstring muscle may cause limitation in range of motion (ROM) that restricts the normal range of muscle. This potentially harmful condition may be managed with a stretching program, which may be positively influence an individual's functional capacity of daily living and decrease of injuries. . Knee extension range of motion from tight hamstring muscle has been linked to injuries such as hamstring tendonitis and hamstring strains. These patient often receive specific hamstring-stretching exercises as part of an overall rehabilitation programme Several studies have reported an immediate increase in knee extension ROM following the application of hamstring stretching exercises.[2,4,5] Flexibility has been defined as the ability of a muscle to lengthen and allow one joint (or more than one joint in a series.) to move through a range of motion². Increased flexibility is one of the basic concerns addressed in the day to day practice of physical therapy. It is a goal for any patient recovery from a period of immobilization or injury involving the connective tissue. Optimal flexibility is also desirable for participants in most athletic activity and normal day to day function. A shortened muscle may create imbalance at joints and faulty postural alignment that may lead to injury and joint dysfunction. Extensibility is defined as the ability to stretch a muscle tendon unit to its fullest length¹. Muscle contracture result in decreased extensibility joint motion. Physical therapists have used many different methods to maintain and increased joint motion and prevent deformity and dysfunction resulting from the muscle contracture. Research with clinical trials has long advocated the use of thermotherapy to increase flexibility in conjunction with a stretching program design to lengthen tissue. Lengthening the musculotendinous unit and supporting connective tissue increase the range of motion(ROM) through which a joint can move as well a the muscle ability to respond to stress placed upon it . [8.14,15,16]

Increased hamstring stiffness could be a possible contributing factor to low back injuries. Clinical observations have suggested that hamstring tightness influences lumbar pelvic rhythm. Movement restrictions or postural asymmetry likely lead to compensatory movement patterns of the lumbar spine, and subsequently to increased stress on the spinal soft tissues and an increased risk of low back pain (LBP). The literature reflects some interesting differences of opinion regarding flexibility training and consideration of static stretching as the gold standard. Some authors have questioned the importance of using static stretching to help reduce injuries and improve performance. Murphy made a compelling argument against the use of static stretching. Although static stretching is often used as part of pre-activity preparation, Murphy argued that the nature of static stretching is passive and does nothing to warm muscle. Murphy suggested a better opinion for maintaining or increasing flexibility of a muscle is through active contraction using dynamic range of motion, there by adding fourth type of stretching. Previous author[1] suggested that most of injuries occur in the eccentric phase of activity. Although early groups have examined dynamic range of motion, none have investigated the use of an eccentric agonist contraction to improve flexibility; eccentric training a muscle through a full range of motion theoretically could reduce injury rates and improve the performance of subject and flexibility. Russel *et al*[2] proved that in males ages 15-17 years old, hip flexion range of motion gains with eccentrically training were equal to those made by static stretching of hamstring muscle. Felipe Jose Jandre Reis *et al*, evaluated Influence of Hamstring Tightness in Pelvic, Lumbar and Trunk Range of Motion in Low Back Pain, and they found that : Participants with LBP showed restriction in the pelvis and TF(trunk flexion) range of motion, but had higher amplitudes in the lumbar spine during forward bending

METHODOLOGY

It is a comparative study. The study has pre-test, post-test experimental group design. Measurement was taken prior to and after respective treatment session at the end of 3rd, 6th and after 2 weeks of follow up on 8th week. There was one independent variable: static stretching and the dependent variable were active knee extension range of motion by 90-90 test, hamstring flexibility, pain and disability.



**Siddiqui Mohammed Aejaz and Amalkumar Bhattacharya****Subjects**

A sample of 29 subjects having mechanical low back pain with hamstring tightness with the mean age of 30.37 years participated in the study. All the subjects were recruited from physiotherapy clinic and health centres in Ahmedabad. To participate, the subjects needed to have tight hamstring muscles (inability to achieve 20° of active knee extension in 90-90 test) & mechanical low back pain. Exclusion criteria included hypermobility, Subject under medication (muscle relaxants), Skin disease, wounds, neurological problem, any circulatory problem or metal implants in the leg. All the subjects were informed the purpose and procedure of the study and an informed consent was taken from them prior to participation.

Instruments

A standard transparent full circle goniometer and a standard stop watch was used.

PROCEDURE

The study was done over 8 week's period with each subject receiving 1 treatment a day for 3 days a week for 6 weeks. Measurement was taken at pre-treatment on 1st day and post-treatment at the end of 3rd and 6th week. The hamstring range of motion of all the subjects were measured after 2 weeks of the last treatment session as a follow up measurement. This group was asked statically stretched for 30 seconds 3 days per week for 6 weeks using methods described by Bandy *et al*³ and Russel *et al*² Subjects performed the hamstring stretch by standing erect with the left foot planted on the floor and the toes pointing forward. The heel of the foot to be stretched placed on a plinth/chair with the toes directed toward the ceiling. The subject then flexed forward at the hip, maintaining the spine in a neutral position while reaching the arms forward. The knee remained fully extended. The subject continued to flex at the hip until a gentle stretch was felt in the posterior thigh. Once this position was achieved, the subject maintained this position for 30 seconds. (Figure.1) Terminal extension is determined as the point at which the researcher felt a firm resistance to the movement. Once terminal extension reached, the researcher holding the goniometer ensure proper alignment and the blinded goniometer is revealed to the assisting examiner for the measurement to be read and recorded. Zero degrees of knee extension were considered full hamstring muscle flexibility. No warm-up was allowed before data collection. Assessment: Pre-test measurements of hamstring flexibility were performed with 90-90 test. Subjects, who found suitable for the study, were requested to sign consent forms. A detailed subjective examination was done. Subjects were also evaluated with pain and disability by using NPRS and Oswestry Disability Index (ODI). This is also taken pre intervention on first day, and at the end of 3rd, 6th and 8th week.

Data Analysis

Means and SDs for all measurements were calculated. The Statistical Analyses was done by using the software: STATISTICAL PACKAGE FOR SOCIAL SCIENCE (SPSS VERSION 16.0) FOR WINDOWS.

RESULTS

A total of 29 subjects, 13 males and 16 females participated in the study. Mean age of the subjects were 30.37±10.41. In our study we have taken 90-90 test, nprs and ODI at pre-test and post week at the end of 3rd, 6th and 8th week. Mean and S.D for pre-test and post-test measurements were calculated for this group. Distribution of the data in the group was analysed by using TEST OF NORMALITY: SHAPIRO-WILK TEST. Level of significance was at 5% with confidence interval 95%. The data was not normally distributed, non-parametric test was applied. Mean and Standard Deviation were calculated for the numeric data. Wilcoxon sign test was applied for comparing the data. Knee extension range of motion between three group were compared at Pre-test (ROM 1), at the end of 3rd week (ROM 2), 6th week (ROM 3) and 8th week (ROM 4).(Table.1) Pre-test mean values for knee extension ROM for group was 139.62±8.92 and respectively (P= 0.001). At end of 3rd week mean values for knee extension ROM for this group was, 143.76±8.77. At the end of 6th week mean values for knee extension ROM for this was 149.00±8.73. At the end of 8th week mean values for knee extension ROM for this group was 145.45±9.06. Pre-test mean values NPRS for our



**Siddiqui Mohammed Aejaz and Amalkumar Bhattacharya**

group was 5.28 ± 1.60 , ($P = 0.001$). At end of 3rd week mean values for NPRS for this is 4.28 ± 1.58 , at the end of 6th week mean values for NPRS for this was 3.48 ± 1.43 . At the end of 8th week mean values for NPRS was 3.21 ± 1.61

Pre-test mean values for ODI for this group was 27.03 ± 9.47 ($P = 0.001$). At end of 3rd week mean values for ODI for this was 24.41 ± 8.97 . At the end of 6th week mean values for ODI for this was 21.86 ± 8.72 . At the end of 8th week mean value was 21.45 ± 8.52 . Since most of the variables are not normally distributed, so non-parametric test has been used for the analysis. Further comparing the range for the pre-test and post-test at the end of 8th week we found that final gain in our study was 5.83. So here we have found that significant difference in comparing to pre and post data.

When going for the NPRS and ODI scale we found the improving result in this group in pre and post data. Means there is significant different in within group analysis.

DISCUSSION

This study was aimed to document the effect of static stretching on hamstring tightness in those who have mechanical LBP. The current study's operational definition of hamstring tightness is a 20° knee-extension deficit with the hip at 90° in a supine lying position. The experimental study involved a total of 29 people. There were thirteen male participants and sixteen female participants. According to this study's operational definition, everyone had tight hamstrings. Flexibility is an important physiological component of fitness, and a lack of flexibility can lead to occupational inefficiency. Muscle tightness is a limiting factor for good physical performance and a significant intrinsic cause for sports injury. Tight hamstrings are an example of a muscle group that has a propensity to shorten. A tense hamstring increases the patellofemoral compressive force, which can cause low back discomfort. Radwan, Ahmed *et al* [22] conducted a study consisting of 72 participants with mechanical LBP including 41 females, 31 males. Hamstring length was detected indirectly using the Active Knee Extension method in the 90/90 position from supine. Thus it was found that persons with LBP had considerably more hamstring tightness than those without LBP. This leads to the conclusion that there is a link between hamstring tightness and LBP. According to the results presented in the preceding section, there is a significant improvement in all three outcome measures: Oswestry scores, NPRS scores, and hamstring tightness for data collected between the first and sixth weeks. After the sixth week, treatment was discontinued, and a follow-up was performed at the eighth week. When the data from the sixth and eighth weeks were compared, it was found that there is an increase in all the three outcome measures. As a result, it was determined that hamstring stretching treatment protocol reduces patients' low back pain, assists them in minimizing hamstring muscle tightness, and improves their functional ability while discontinuing the hamstring stretching treatment protocol increases low back pain and hamstring muscle tightness, as well as causes functional disability due to low back pain. Another study supported by Nelson RT, Bandy WD (2004)² consisting of 69 high school males with limited hamstring flexibility were recruited. Their objective was to determine if high-school-aged males' flexibility improved after a 6-week eccentric exercise programme. Furthermore, the changes in hamstring flexibility observed following the eccentric programme were compared to a 6-week static stretching programme and a control group (no stretching). They found that the gains made in range of motion of knee extension (indicating improvement in hamstring flexibility) with eccentric training were equal to those made by statically stretching the hamstring muscles. Thus, stretching programmes could be developed by therapists in the community as part of a workplace educational component. This would promote wellness, prevention, and treatment for mechanical LBP patients.²²

CONCLUSION

This study shows that static stretching, is effective in increasing hamstring flexibility of patients with mechanical low back pain there is significant improvement seen in hamstring muscle flexibility along with reduction in low back pain and improvement in functional disability This result suggests that there is further scope for the use of flexibility training in individual muscle group in a more functional type of activity and also work on patients with low back pain.





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Table.1: Within group comparison

	Mean	Std. Deviation
Age	30.38	10.41
ROM 1	139.62	8.92
NPRS 1	5.28	1.60
ODI1	27.03	9.47
ROM 2	143.76	8.77
NPRS 2	4.28	1.58
ODI 2	24.41	8.97
ROM 3	149.00	8.73
NPRS 3	3.48	1.43
ODI 3	21.86	8.72
ROM 4	145.45	9.06
NPRS 4	3.21	1.61
Odi 4	21.45	8.52

Table.2: Pre-test, Post-test and gain ROM

	Static stretching	
	Mean	SD
Pre test	139.62	8.92
Post test (8 th week)	145.45	9.06
Gain	5.83	0.15

Gain = difference between pre and post

Table.3: Pre-test, Post-test and gain NPRS

	Static stretching	
	Mean	SD
Pre test	5.28	1.60
Post test (8 th week)	3.21	1.61
Gain	2.07	0.01

Gain = difference between pre and post

Table.4: Pre-test, Post-test and gain ODI

	Static stretching	
	Mean	SD
Pre test	27.03	9.47
Post test (8 th week)	21.45	8.52
Gain	5.58	0.95

Gain = difference between pre and post





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Figure.1: Subject doing self-stretching of Hamstring Muscle



Figure.2: Measuring hamstring flexibility with Goniometry (90-90 test)

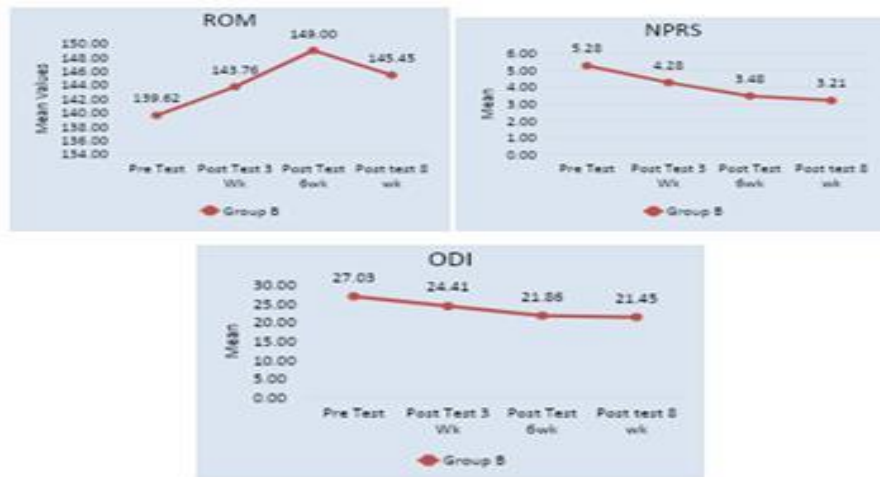


Figure.3: Mean change (difference between pre and post) in ROM, NPRS and ODI





Isolation, Molecular Identification and Metabolite Screening of Endophytic Fungi from *Tinospora cordifolia*

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ABSTRACT

The study aimed to extract three different types of endophytic fungi, including *Lasiodiplodia parva*, *Mucor* sp., and *Fusarium oxysporum*, from *Tinospora cordifolia*. The antimicrobial properties of the fungal metabolites were tested against various human pathogens such as *Staphylococcus* sp., *Klebsiella* sp., *Pseudomonas* sp., and *E. coli*. Enzyme screening revealed that *Lasiodiplodia parva* generated protease, lipase, and amylase; *Mucor* sp. produced lipase and cellulase, and *Fusarium oxysporum* synthesized protease. Secondary metabolites of *Mucor* sp had the strongest antibacterial effect on *E. coli* (21 mm). *Fusarium oxysporum* and *Lasiodiplodia parva* both showed modest activity against *Staphylococcus* sp., each with a 14 mm inhibition zone.

Keywords: fungal endophytes, *Tinospora cordifolia*, secondary metabolites, antibacterial activity, Extracellular enzymes.

INTRODUCTION

The increase of world's population leads to changes in lifestyles, settlements, diets, and hygiene. Medicinal plants offer important compounds for medicines [1]. 80% of the world's population use herbal products for healthcare and immune support [2]. *Tinospora cordifolia*, (Guduchi), is an herbaceous vine from the *Menispermaceae* family native to India. It contains secondary metabolites such as palmatine, tinosporide, β -sitosterol, phenylpropanoids, norditerpene





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furan glycosides, diterpene furan glycosides, and phytoecdysones. These phytochemicals are used to treat dyspepsia, fevers, urinary diseases, antimicrobial, anticancer, antiperiodic, antispasmodic, antipyretic properties and anti-inflammatory [3]. Endophytic fungi, which produce compounds similar to those of their host plants, offer a great impact on drug development. This study emphasizes identifying fungal endophytes from *Tinospora cordifolia*, investigating their extracellular enzyme production and antibacterial activity against pathogenic bacteria.

MATERIALS AND METHODS

Isolation of Endophytic fungi

Tinospora cordifolia, collected from Kerala for its suitability to the tropical climate, and its root was surface-sterilized for the isolation of endophytic fungi, and Lactophenol cotton blue staining was used to determine morphological characteristics [4].

Molecular Identification

Genomic DNA was extracted using the method [5]. The nuclear ribosomal DNA region (18S rRNA) was amplified with universal primers ITS1 (5'-GGAAGTAAAGTCGTAACAAG-3') and ITS4 (5'-TCCTCCGCTTATTGATATAGC-3'). The resulting PCR products were visualized on a 1% agarose gel, and sequencing was performed using an ABI 3630 sequencer.

Screening of Extracellular Enzymes

Amylase activity was assessed using the method [6]. Protease activity was evaluated [7]. Lipolytic activity and cellulase activity both were also analyzed [8, 9].

Production of Secondary Metabolites and its Antimicrobial activity

The secondary metabolites were extracted [10], and their antibacterial activity was evaluated [11].

RESULT AND DISCUSSION

Isolation of Endophytic Fungi

Three endophytic fungi were isolated from the root of *Tinospora cordifolia*, labeled as TR1, TR2, and TR3 (Fig 1 & 2).

Morphological characteristics

TR1: Greenish-black, flat, circular colonies with a flat elevation.

TR2: White, circular colonies with a raised elevation.

TR3: Irregular colonies with an orange-red center, flat elevation, and filiform margin.

Molecular Identification

TR1 had 88% sequence identity to *Lasiodiplodia parva*, TR2 showed 96% identical matches to *Mucor sp.*, and TR3 had 97% similarity to *Fusarium oxysporum*. The consensus sequences were deposited in GenBank, and its accession numbers were PP593602 (TR1), PP593605 (TR2), and PP593607 (TR3) (Fig 3 & Table 1).

Screening of Extracellular Enzyme

Three endophytic fungal strains were isolated from the root of *Tinospora cordifolia* were screened for their extracellular enzyme activity such as amylase, lipase, protease, and cellulase. Both *Lasiodiplodia parva* and *Fusarium oxysporum* evidenced protease activity by clear zone around the colony upon the addition of saturated ammonium sulfate. All the three fungal isolates indicated a crystalline precipitate around the colony due to lipase activity upon the addition of Tween 20 (fig. 4). After the addition of iodine, *Lasiodiplodia parva* and *Fusarium oxysporum*, demonstrated amylase activity by a clear zone around the colony. Cellulase activity in *Mucor sp.*, and *Fusarium oxysporum* was confirmed by the presence of a clear zone by applying Congo red (fig 4). These results highlighted that endophytic





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fungal isolates can secrete different extracellular enzymes capable of degrading lipids, cellulose, proteins, and starch. This enzymatic activity suggests their potential applications in agriculture and the health care. Fungal enzymes are more stable compared to animals and plants, making them ideal for large-scale production [12].

Antibacterial Activity

Fusarium oxysporum revealed the highest activity against *Staphylococcus sp.* with a 14 mm inhibition zone, and 11 mm against *Klebsiella sp.* *Mucor sp.*, showed potent activity against *E. coli*, resulting in a 21 mm zone, while *Staphylococcus sp.* had an 8 mm zone. *Lasiodiplodia parva* also displayed strong activity against *Staphylococcus sp.* with a 14 mm inhibition zone and a 9 mm zone against *Pseudomonas sp.* The study highlighted the capability of endophytic fungi to produce natural compounds with inhibitory effects against human pathogens [13].

CONCLUSION

Tinospora cordifolia plant's root contains diverse endophytic fungi, such as *Lasiodiplodia parva*, *Mucor sp.*, and *Fusarium oxysporum*. These fungi proved to produce extracellular enzymes and secondary metabolites with therapeutic applications due to their antibacterial properties. Further research is essential to identify and analyze specific compound produced by these fungi.

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Table.1: Blast Sequence identity of endophytic fungi

Isolates	Accession Number	% Identity	Species
TR1	PP593602	88%	<i>Lasiodiplodia parva</i>
TR2	PP593605	96%	<i>Mucor</i> sp.
TR3	PP593607	97%	<i>Fusarium oxysporum</i>

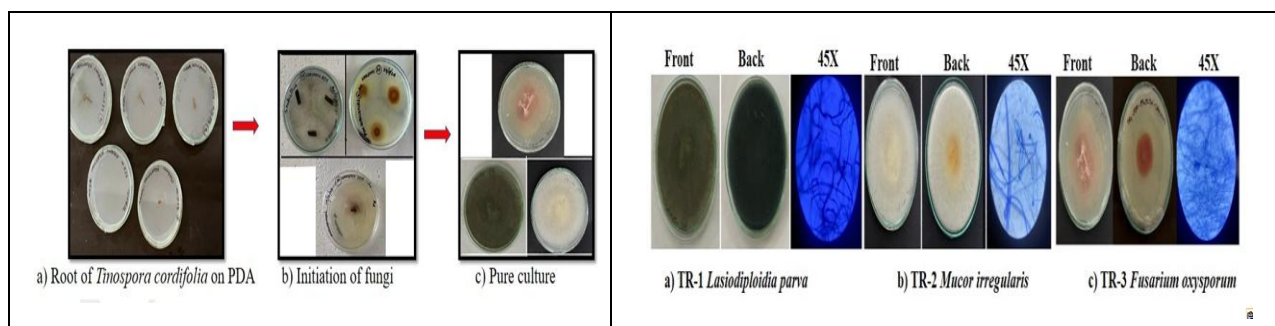


Figure.1: Isolation of Endophytic Fungi

Figure.2: Microscopic Examination

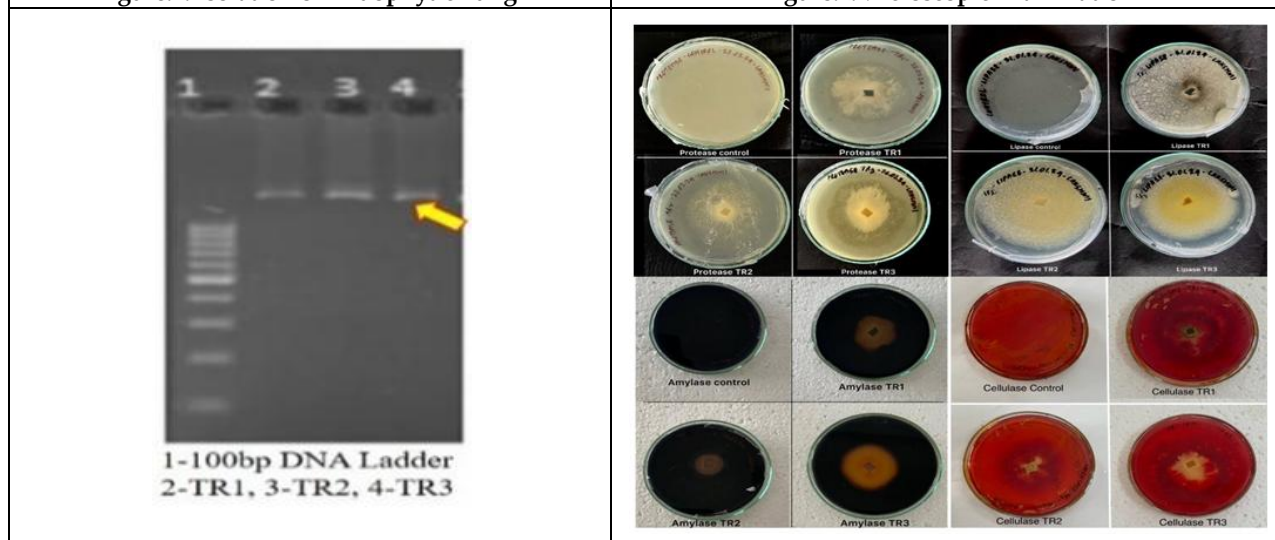


Figure.3: PCR Products of Endophytic Fungi

Figure.4: Screening of Extracellular Enzymes in Endophytic Fungi





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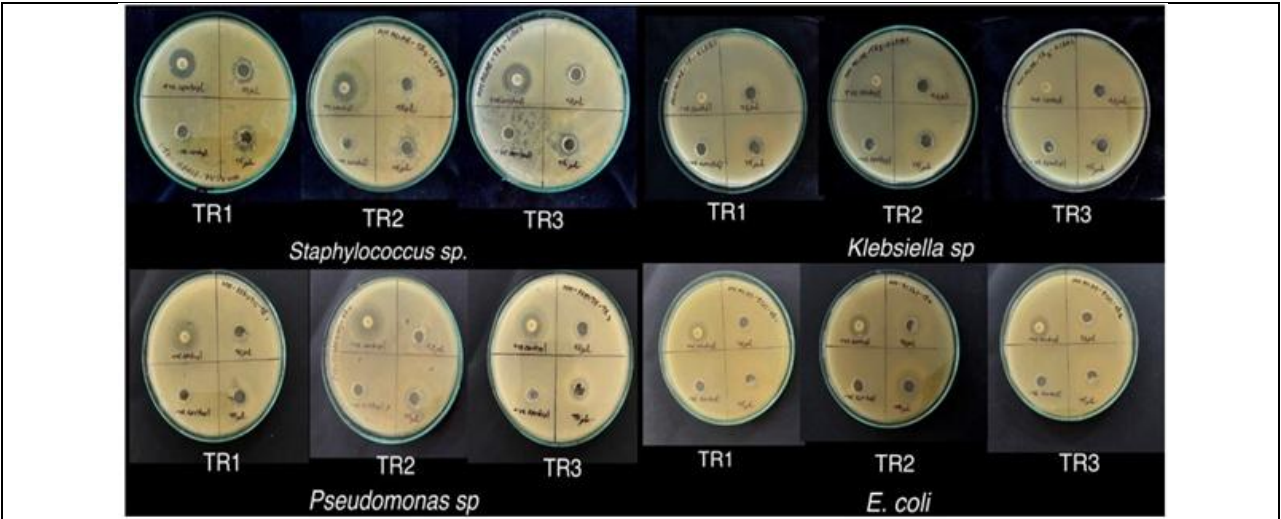


Figure.5: Anti-Bacterial Activity





Advanced Clinical Use of Mass Spectrometry in Toxicology

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ABSTRACT

Mass spectrometry, once considered an expensive and specialized technology, has now become a common tool in many clinical laboratories. It is the preferred technique for rapid sample analysis and is widely used in various applications. For example, HRMS is a popular method for analyzing new drugs, while MS/MS is used for the clinical study of amino acids in plasma and blood. Additionally, elemental analysis by ICP-MS is now widely used in clinical laboratories for the quantitation of toxic metals and trace elements in a wide range of samples. Mass spectrometry plays a significant role in human sport doping management, toxicology applications, drug analysis, and hazardous metal tests. The introduction of sophisticated MS platforms such as tandem mass spectrometry (MS/MS), time-of-flight (TOF), and Orbitrap systems has revolutionized the detection of a wide range of medications, metabolites, and toxins in complex biological matrices such as blood, urine, and tissue samples. These technologies assist both normal and emergency clinical applications by enabling precise quantification of chemicals at trace quantities, quick screening, and confirmatory testing. The advanced uses of MS in toxicology are explained in this review, with particular attention paid to different setups, approaches, and the clinical relevance of using MS in both standard and specialist toxicology labs.

Keywords: Mass spectrometry, ICP-MS, Clinical applications, Clinical toxicology, Forensic toxicology



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INTRODUCTION

In recent years, mass spectrometry (MS) once thought to be an extremely expensive and specialized technology for everyday use has become common place in many clinical laboratories. Technology advancements, the introduction of bench top systems, improved operational simplicity, lower capital requirements, and more user-friendly software systems have all contributed to this quick expansion. Mass spectrometry has become a very attractive platform for clinical practice due to recent developments. However, the implementation of this technology in many routine clinical laboratories is hindered by apprehension due to its complexity, relatively high capital investment, personnel training, and requirement for in-house method development and validation(1). The foundation of MS is in its capacity to impact charged particles' motion using electric and magnetic fields. As a result, charged particles can be separated according to their mass-to-charge (m/z) ratios. Mass spectrometry is a device that weighs molecules that have been transformed into ions. For an analysis to be performed by a mass spectrometer, the analytes must be ionized, or positively or negatively charged. Furthermore, any other charged or possibly ionizable substances present in the sample may act as an interference for the target analyte. Samples must be handled carefully before analysis, and sample preparation can range from "dilute and shoot" to a highly involved process. Extractions in the liquid-liquid or solid-phase are frequently employed(2). Although materials can be put straight into a mass spectrometer, the usual procedure for separation involves first isolating the desired chemicals from the matrix using gas or liquid chromatographic techniques. The chromatograph's effluent is ionized upon separation. The mass-to-charge ratio of the generated ions is used by the mass analyzer to separate them. In the end, the data analysis system reports the ions that have been "recorded" in the detector(3). Fig. 1 displays a schematic diagram of a general mass spectrometer. Mass spectrometry is the preferred technique when a rapid sample analysis is required. Chromatography-MS techniques differ largely at the sample introduction. The components of the MS instrumentation are the ion sources, detector, and mass analyzer. The problem of forensic analysis lies in the possibility of lowering the time and cost of analysis each sample. One of the primary analytical objectives of toxicology is to ascertain whether drug metabolites are present in biological samples or not. In this sense, the ambient ionization technique in conjunction with mass spectrometry has enabled full sample analysis without requiring extensive sample preparation. The idea of open-air surface examination directly under ambient circumstances is made possible by these technologies, which are particularly useful for surface investigation of materials avoiding many, if not all sample preparation steps typically required(4). High-Resolution Mass Spectrometry (HRMS) can distinguish between compounds with similar nominal masses and measure masses accurately, it is currently used extensively in conjunction with ambient mass spectrometry to provide full-scan MS and MS/MS data that can be used to search for any analyte without the need for sample pre-treatment. As a result, precise m/z values are provided which can be utilized to create chemical formulae with a mass accuracy of less than 5ppm. Since HRMS may be used in many configurations with interchangeable ionization sources and advanced data collecting capabilities, it is a popular method for analyzing new drugs(5). The categorization of ambient ionization mass spectrometry is based on the desorption technique, which will be covered in the upcoming commonly employed methods for analyzing drugs of abuse(6).

ESI Interface

As mentioned earlier, during an Electro spray Ionization (ESI) analysis, the mobile phase helps get the sample to the source. The LC capillary tip, which is surrounded by the drying gas stream (usually nitrogen at a flow rate of 5–15 ml min), is where the desolvation process begins. The Taylor cone is formed by eluent surface deformation in an electric field (potential differences between the heated capillary and the LC capillary tip can reach up to 5–8 kV). While skimmers capture neutral particles and other impurities, the stream of dry ions reaches the mass spectrometer due to another electric potential difference, this time between two ends of the heated capillary. Analyte ions are subsequently sent to the analyzer for quantification. Skimmers are crucial because they keep the instrument's differential pumping inside. In order to force in-source fragmentation, potentials between the heated capillary and skimmers can be adjusted. All ions will fragment in this way, hence pure material must be injected to prevent the formation of a complex mixture of fragmented ions originating from different molecules(7).





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APCI Connection to MS

APCI (Atmospheric Pressure Chemical Ionization) takes place when the charge transfer reactions that result in the production of ions in the vapour phase. With the exception of applying a high potential (corona discharge) to the spraying zone, which is the area between the MS inlet and the LC needle, this interface is constructed similarly to ESI. A setup like this generates an electric discharge that successfully ionizes the surrounding gas molecules and charges the mobile-phase species. These charges are then transferred to the analyte molecules via charge exchange or proton transfer. When analyzing small compounds that don't break down thermally, an APCI source is used. In comparison to standard ESI interfaces, it can handle larger flow rates (8).

APPI Interface

Photoirradiation is used to ionize the desolvated droplets, often with the aid of a krypton lamp (10eV). Photons are absorbed by analyte molecules, which then transform into ions when the supplied energy surpasses the species ionization potential. This process can be run in both positive and negative modes, just as ESI. Irradiation in the spraying zone is made possible by the connection of APPI (Atmospheric Pressure Photoionization) with the chromatographic column for the identification of molecules that are difficult to ionize, such as weakly polar or nonpolar analytes (9).

LC Connection to MALDI-MS

An example of an offline connection type would be connecting LC to MALDI-MS (Matrix Assisted Laser desorption/ionization – Mass Spectrometry). Once the spotter is attached to the LC capillary output, automation of the process is simple. Automatically handling the eluent and depositing fractions on the Matrix Assisted Laser desorption/ionization (MALDI) target plate is the function of the fraction collector, also referred to as the spotter. Tiny amounts of LC eluent usually 5–50 µl, can be accurately detected. Furthermore, matrix solution is automatically added. This makes it possible to prepare target plates without the operator's help. This interface allows for a very large sample capacity and allows for the observation of many target plates. The MS analysis might be shortened by spotting samples at different times. Piezoelectric spotters are also used to deliver much smaller nanoliter amounts (10). MS/MS is used in the clinical investigation of amino acids in blood and plasma using liquid secondary ionization, often known as fast ion bombardment (FIB). Manual sample introduction techniques were required in the initial study. Semi-automatic flow injection was created using FIB ionization to facilitate automated sample introduction and boost throughput (11). This method was somewhat challenging however, due to problems with sample retention on the probe tip and frequent capillary occlusion at the probe surface. The introduction of electrospray ionization greatly enhanced automated sample analysis and sample throughput. After successful validation processes used in clinical amino acid investigations or newborn screening, ESI-MS/MS has been demonstrated to be a rapid, accurate, and dependable method for high sample volume, fast throughput and amino acid assays (12).

Gas Chromatography Combined with Mass Spectrometry (GC-MS)

Since LC analysis is done in solution, ionization sources like pressure chemical ionization (APCI) and ESI can be connected online to the LC system. In contrast, the chromatographic apparatus requires an offline connection for the MALDI source. The solvent flow rate is the most crucial factor to consider. The basic norm is that sensitivity increases with decreasing flow rate. This means that although flow rates ranging from 0.1 to 1 ml/min can be used, flow rates as low as 100–500 nl/min provide the best sensitivity results. A nano ESI is connected for direct to MS in these situations (13). Inductively coupled plasma ionization (ICP), which is commonly used for metals determination using ICP-MS, and matrix aided laser desorption ionization (MALDI) which is used to ionize solid samples for MS analysis, are further ionization techniques for elemental analysis. Since MALDI techniques are not commonly utilized in toxicological applications they will not be used. Additionally the emphasis will be on the more popular EI, ESI, and ICP ionization techniques used for toxicological applications, even though modern GC-MS and LC-MS equipment can normally switch between EI/CI and ESI/APCI ionization methods, respectively (14). Among the advantages of LC-ICP-MS are its ability to measure numerous elements, metal speciation, and a wide dynamic range with precise and accurate trace metal readings. ICP-MS frequently has detection limits in the low ng/L range, which is useful for





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measuring trace elements or dangerous metal concentrations that are low. One significant disadvantage of ICP-MS applications for metals analysis is polyatomic interferences. These kinds of interferences happen when two or more atomic ions from the sample matrix units to produce molecules that have the same m/z as analytical targets. For example, argon plasma gas (40 Da) can be combined with a chloride ion (35 Da) or carbon (12 Da) from the biological matrix to produce argon chloride (75 Da) and ArC (52 Da) ions. ArCl and ArC have the same m/z as arsenic and chromium, two elements that are commonly included in harmful metal surveys employing ICP-MS. In order to increase specificity by reducing isobaric or polyatomic interferences, several collision/reaction cell applications for ICP-MS have been developed thus far. In order to counteract isobaric interferences from the plasma, quadrupole ICP-MS devices employ dynamic reaction cells (DRCs), which react a reactive gas with either the analyte (ion) of interest or an isobaric molecule (ion) to separate the two. Alternatively, the quadrupole may work as a collision cell in the presence of an inert gas. In this scenario, it will interact more favorably with polyatomic ions that have larger radius, lowering their kinetic energy and enabling kinetic energy discrimination (KED) to resolve polyatomic interferences from the target analyte. Polyatomic interferences can be broken up using collision-induced dissociation (CID) in a triple quadrupole ICP-MS/MS before MS detection, or they can be resolved using a higher resolution instrument (such as a double focusing sector ICP-MS) by precisely determining mass. The quantification of toxic metals and trace elements in a variety of samples, such as whole blood, serum, plasma, urine, and dry spots of these liquid samples (using laser ablation with ICP-MS), is now done in clinical laboratories due to the high specificity, sensitivity, and reproducibility of elemental analysis by ICP-MS. Samples must be collected in tubes free of metal in order to produce accurate results. Other sample types used in forensic toxicology include urine, hair, nails, tissue, and other forensic materials (15).

Clinical Toxicological Assay

Toxitude A1 (used for solid-phase extraction) and 5 ng/mL of deuterated (d_5) analogues were used as internal standards (IS) for the extraction of urine and blood. Following ten minutes of horizontal stirring and five minutes of centrifugation at 3500 rpm, the organic extract was poured into a glass tube and allowed to evaporate at room temperature while being gently blown dry with a mild airstream. After the fragments were put into glass vials, 250 mL of methanol was used to reconstitute them. The chromatographic system was injected with ten microliters using a partial loop injection mode (16). Hair extraction to remove fat residues from hair, ethanol was used once and dichloromethane was used twice for five minutes each time. As internal standards, the hair was cut into sections using scissors, and 20 mg of cleansed and chopped hair were treated with 100 pg/mg of deuterated amphetamines and analogues. Hair samples were digested with 1 M sodium hydroxide for 15 minutes at 80°C. Three milliliters of a hexane/ethyl acetate (2/1) combination were used for a ten-minute liquid-liquid extraction. After centrifugation, the organic layer was filtered through Polytetrafluoroethylene (PTFE) 0.2mm and allowed to evaporate at ambient temperature. Glass vials containing 100 mL of a 50/50 methanol/water solution were used to reconstituted the residues. The chromatographic apparatus was injected with ten microliters (17).

Drug analysis by GC-MS

Regular applications with the sensitivity and specificity of MS could be created by combining GC and MS. GC is an analytical separation technique that separates molecules into gas and stationary phases. It makes use of a gas mobile phase and a liquid or polymer stationary phase. The process usually involves high temperatures or temperature gradients (up to 350°C) to promote compound elution into the mobile gas phase. The analytes are separated into groups according on their column retention durations, and then they go into the gas phase of the MS for ionization. To help with MS detection, EI sources are frequently used. By employing the kinetic energy of a stream of high energy electrons (typically 70 eV) to extract electrons from analyte molecules at high temperatures, EI ionization produces a consistent fragmentation pattern from organic substances. As a result, extensive EI-GC-MS libraries have been developed for identification based on spectrum matching, and interlaboratory spectral comparisons benefit from EI-GC-MS data. These libraries greatly improve GC-MS based compound identification and supplement "in-house" produced libraries. EI-GC-MS is presently a very successful technique for the untargeted detection and quantification of tiny molecules with MS specificity due to this analytical advantage. EI-GC-MS is still used for broad unknown screening applications with nearly any kind of sample. Additionally, GC-MS is commonly used to validate





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IA positive results from drug screens in clinical toxicology. The correct functioning of GC-MS requires that the analytes be both heat stable and volatile. Therefore, in order to render the drugs sufficiently volatile for GC-MS analysis, some analytes need to be chemically derivatized. This limits GC-MS's ability to investigate a wide range of drugs and raises the costs and complexity of sample preparation procedures.

Clinical Applications of MS in Toxicological investigations

The diagnosis or definitive exclusion of an acute or chronic poisoning is crucial in clinical toxicology. Patients who are dependent on illegal substances, alcohol, or medications also need to be monitored closely. There are many different areas in forensic toxicology, and each has different requirements for the breadth and depth of screening. Broad-spectrum screening is recommended in the following areas: post-mortem toxicology, driving while intoxicated, child welfare, drug-facilitated crime, and investigation. Drug testing in the penal system, the workplace, and the military forces are among the settings focused on drugs of abuse. The same kinds of specimens used in clinical toxicology are also used in clinical forensic toxicology. But unlike clinical toxicology, the forensic environment places more value on analytical findings that can be supported in court. As such, a confirmation step ought to be conducted in conjunction with screening in forensic toxicology, either concurrently with the same analytical run or independently. Considering that someone who tests positive for an unlawful drug may face consequences, the treatment of drug-dependent individuals falls between the horizon of clinical and forensic toxicology. It is standard practice in post-mortem toxicology to use two distinct specimens and two distinct procedures. Because of the varied and frequently deteriorated character of the specimens as well as the wide variety of specimens accessible for investigation, applying analytical techniques in post-mortem toxicology is frequently more challenging than in other forms of forensic toxicology. It is important to thoroughly validate methods for the specific post-mortem specimen being used. In addition to blood, urine and vitreous humour can be useful specimens. In certain situations, solid tissues like the liver and the contents of the stomach can also be used(18). Uses for human sport doping management Early uses of TOFMS in doping control included quantitative measurements of β 2-agonists and qualitative specific analysis of steroids. Initially, TOFMS was applied to a single target analyte or a specific class of chemicals, as opposed to a variety of distinct compound kinds. The most popular ionization method is ESI because it works well with polar metabolites and a variety of target analytes, ranging in size from small to big molecules. Analysis of non-polar anabolic androgenic drugs has been done using APCI(19). As of right now, For use in toxicology, MS and its hyphenated applications (GC/LC/ICP-MS) are powerful analytical tools. Generally speaking, elemental analysis is carried out using ICP-MS for metals determination, non-volatile and heat-labile compounds are analyzed using LC-MS, and volatile and heat-stabilized compounds are studied using GC-MS. Because of the analytical versatility of MS methods which have exceptional specificity, sensitivity, dynamic range, and the ability to screen a vast number of unrelated substances. MS applications are crucial for toxicological evaluation of pharmaceuticals and toxins. In addition to specialized applications (like TDM and pain management) and screening applications (like drugs of abuse (DOA), forensic toxicology, environmental toxicology, and clinical toxicology), drug analysis is currently utilized in pharmacokinetic/pharmacodynamics (PK/PD) research. Here we concentrate on the capabilities and corresponding toxicity applications of GC-MS, LC-MS, ICP-MS, and MS/MS(20).

Applications of MS/MS and LC-MS

- A. The initial use of MS/MS was for the clinical investigation of amino acids in blood and plasma using liquid secondary ionization (fast ion bombardment, or FIB). Manual sample introduction techniques were required in the initial study. Semi-automatic flow injection was developed using FIB ionization to facilitate automated sample introduction and boost throughput. However, this method was somewhat time-consuming due to problems with sample retention on the probe tip and frequent capillary occlusion at the probe surface. The introduction of electrospray ionization greatly enhanced automated sample analysis and sample throughput. After successful validation processes used in clinical amino acid investigations or newborn screening, ESI-MS/MS has been demonstrated to be a dependable, quick, and accurate method for high sample volume, fast throughput, and amino acid assays (21).





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- B. One new use of protein profiling in proteomics and MS is the identification of bacterial isolates. Bacteria are isolated from unkind individuals, cultivated on agar plates for a night, and then cleaned. A 500 nL sample from one colony is cleaned and diluted. After that, a stainless steel target was placed on 500 ml of the diluted solution and an equivalent volume of sinapinic acid matrix, and MALDI-ToF analysis was performed. The top panel shows a spectrum of *Escherichia coli*, and the bottom panel shows a spectrum of *Staphylococcus aureus*. *S. aureus* was digested using lysozyme, which is seen in the spectrum as the big peak at 14000 Da. Even if most individual proteins or peptides are not found in these spectra, the profiles for each bacterial isolate are unique. This suggests that MS may be able to identify bacteria based on a distinct peptide pattern or fingerprint. The reproducibility of data indicates that research and development efforts are concentrated on creating fingerprint (interpretation) design and industrial high-throughput technologies. The FDA's analytical scientists are coordinating efforts to standardize protocols. The process of identifying tumor markers. Tumor marker identification and characterization represents another possible application of protein profiling in clinical laboratory settings. The following laboratory data were microdissected from a single patient's frozen tissue using laser capture micro dissection, normal breast epithelium, invasive ductal carcinoma of the breast, and metastatic ductal carcinoma. It is evident that the spectra of tumor cells differ from those of normal cells. This "fingerprint" acts as a quick identification tool for different kinds of tissue. It might be especially helpful in determining the original site of metastasized malignancies.
- C. MS is the best instrument for analyzing altered or peculiar nucleic acids, nucleosides, or nucleotides. These DNA components lend themselves very well to examination using electrospray ionization. Numerous techniques have been published for measuring nucleic acids particularly in the context of tumor marker urine. When it comes to oligonucleotide analyses, these little DNA fragments are a great indicator of disease-causing mutations. There are various more genetic uses of MS in clinical research that are more adequately and thoroughly addressed in other studies. New assays have been created for clinical illnesses.

GC-MS applications for toxicology

When compared to its LC-MS/MS counterpart, GC-MS does have a few advantages. These include: improved chromatographic resolution and peak capacity for efficient GC separation, a homogenous gas mobile phase (typically hydrogen or helium), precise electronic controls for temperature programming to optimize separation conditions, and the capacity to search EI-MS databases for library-based toxic compound identification. When paired with good MS sensitivity (1–10 µg/L) and specificity, GC-MS is a prominent tool for the general screening of unknown drugs or harmful compounds in doping control, environmental analysis, and clinical and forensic toxicology (22). In doping control, environmental analysis, and clinical and forensic toxicology, GC-MS is a widely used method for the general screening of unknown substances or hazardous compounds when combined with good MS sensitivity (1–10 µg/L) and specificity (22). Additionally, it is frequently employed in forensic investigations and clinical evaluations of toxidromes to conduct drug screenings for the purpose of identifying and quantifying poisons. GC-MS is commonly used to quantify a variety of medications, including barbiturates, opioids, stimulants, anaesthetics, anticonvulsants, antihistamines, anti-epileptic drugs, sedative hypnotics, and antihistamines. In environmental toxicology, GC-MS can be used to easily screen for a variety of hazardous compounds, including sulfur analysis in air, dioxins, dibenzofurans, organo-chlorine pesticides, herbicides, phenols, halogenated pesticides, chlorophenols in water and soil, or polycyclic aromatic hydrocarbons (PAH). One point to note is that for targeted drug screenings in clinical and forensic toxicology applications, the majority of toxicology laboratories with the financial means are gradually switching from GC-MS to LC-MS. Last but not least, because MS detection has a higher specificity than enzymatic spectrophotometric tests, GC-MS is occasionally used to identify and quantify volatile chemicals in bodily fluids including blood and urine, such as ethanol, methanol, acetone, isopropanol, and ethylene glycol(23).

ICP-MS applications in clinical toxicology

ICP-MS is commonly used for multi-analyte hazardous metal testing in whole blood, plasma, serum, and urine. Both acute and chronic metal exposure can generally be assessed using blood and urine analysis, and the results can be better understood by comparing them to reference values from other parts of the world. More recent applications of laser ablation in conjunction with dried blood or urine spots for multi-analyte metal analysis have been reported. The





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multi-analyte ICP-MS metal panels can include up to dozens of targets, including lead, mercury, arsenic, cobalt, chromium, manganese, molybdenum, nickel, titanium, aluminum, and silver. Because lead has negative effects on development, it is frequently examined in children. Exposures can also happen from older lead water pipes in buildings, paint that contains lead, or environmental buildup from gasoline that has historically contained tetraethyl lead. Eating carnivorous fish can expose oneself to mercury exposure because these species typically have high levels of mercury in them due to environmental contamination. There have also been reports of exposures to mineral mercury leaking from dental amalgams. To differentiate exposures from seafood and dental amalgams, mineral mercury is often measured in plasma and methylmercury (MeHg) in whole blood. Although arsenic has been used to deliberately poison people, contaminated ground water can also unintentionally expose people to the chemical. It has been demonstrated that individuals with different metal replacement joints or dental implants have toxic levels of cobalt, chromium, manganese, molybdenum, nickel, and titanium. In addition to being the focus of toxicological debates linked to vaccine side effects, aluminum is frequently measured in plasma to monitor hemodialysis patients. Although silver has long been employed as an efficient bactericide, excessive exposure to metal can cause argyria as well as neurologic, hematologic, renal, or hepatic involvement with blood silver hazardous levels, according to reports (24).

ICP-MS applications in forensic toxicology

Metal poisoning deaths are rare and frequently unexpected, blood testing for conventional metal poisons (such as arsenic and thallium) toxic heavy metals (such as arsenic, lead, cadmium, and mercury) other toxic metals (such as aluminum, chromium, cobalt, molybdenum, nickel, vanadium, or tungsten) or drugs (such as contrast media) is frequently performed in relation to all unexplained deaths. ICP-MS forensic metals analysis has the benefit of accepting sample types other than blood or urine. Forensic or clinical toxicology analyses a variety of samples including hair and nails by combining laser ablation with ICP-MS detection. Urine and blood typically indicate exposure during the previous few hours or days. Hair is a cumulative sign for longer-term exposure as opposed to blood or urine. One centimeter of hair can be used to check for a longer window of exposure because it can represent one month of exposure in clinical and forensic toxicology research. It is possible to differentiate between a single exposure and a chronic exposure by comparing blood or urine data with hair samples from a particular developmental stage. Additionally, nails can serve as a biomarker for forensic metals analysis using ICP-MS. During linear growth and thickening, blood components are integrated into nails, providing a three to five month window for detecting exposure to dangerous metals (25). Because nail collections are non-invasive and contain more disulfide groups, which aid in incorporating more metal content, they are a preferred matrix for metals analysis when hair is unavailable due to balding or other conditions (such as religious views). This allows for a longer window of detection. Lastly, when external contamination affects hair and nails and blood and urine are not available, or when biopsies of specific organs need to be checked for metal buildup, tissue and biopsies for metals analysis by ICP-MS become essential (26).

ICP-MS applications of hair, nails & tissues in clinical toxicology & forensic toxicology

Along with more conventional matrices like blood and urine, ICP-MS analysis of metals and metalloids applied to hair, nail, and tissue in clinical toxicology and forensic toxicology has been gradually rising. Since each centimeter of hair represents the exposure over the previous month, hair and nails are important cumulative biomarkers of long-term exposure, unlike blood or urine, which only reflect exposure over the previous few days or hours. This makes it possible to date exposure and is very helpful in interpreting results from forensic and clinical toxicology. In addition, the sample size is less and the hair and nail collection is non-invasive. Quantification of metal in tissues is another interesting application, especially in forensic circumstances where standard fluids like blood and urine are unavailable (27).

ICP-MS applications to hair

Arsenic in hair was the first instance of xenobiotic analysis in this matrix around the end of the 1800s. The metallic profile of hair as measured by ICP-MS is a special challenge because it indicates exposure to a broad panel of elements over a lengthy period of time, with each centimeter representing a month. Hair samples, which can be





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utilized to differentiate between a single exposure and continuous contact by segmenting the hair during a specified growth period, are required in addition to blood and urine tests. Moreover, hair can be an important clinical and forensic specimen when the metal content of normal biological materials, such as blood and urine, has been eliminated by natural processes. Cleaning procedures, sample digestion, analytical techniques (especially ICP-MS), the normal ranges of metals and metalloids in hair, and data interpretation are all included in the examination of hair. Hair metals and metalloids should be regularly cleaned with acetone and water, according to the International Atomic Energy Agency. To break down the organic matrix, an acid sample of roughly 20 mg is usually mineralized after the washing procedure. After that, an ICP-MS analysis is performed on the diluted solution. However, because of irreversible external contamination, metal/metalloid hair analysis is not recommended to monitor occupational professional exposure to elements. Recent thorough evaluations of hair analysis can be useful to complete this section. To record exposure to these elements, metals and metalloids in hair must be analyzed in addition to the routine usage of biological fluids such as blood and urine (28).

ICP-MS applications to nails

Because they have more disulfide chemical groups than hair, which let them retain more metals and metalloids, fingernails and toenails have some advantages over hair. In addition, nail development is more consistent than hair growth and is less impacted by hair-related cosmetics. Furthermore, since shoes shield toenails from the elements, hair is less susceptible to pollution from the outside world than toenails. One major disadvantage is that the section corresponding to a recent exposure is located in the matrix, making it challenging to access. Since elements are incorporated into nails through the nail bed during thickening growth and blood assimilation into the matrix during linear growth, the presence of elements in nail clippings is linked to a prior exposure of three to five months. There are a lot of published studies on this topic that use either single or multi elemental analysis. Certain series have compared the element concentrations in the same person's hair and nails, fingernails and toenails, and sometimes urine. These scientists concluded that for measuring element exposure overall, toenails in particular are better indicators than hair. In conclusion, nail collection is a non-invasive and intriguing substitute for hair, especially for bald individuals or those who are prohibited from having their nails sampled for religious purposes. In human toxicology, nail analysis can be viewed as an adjunct to hair analysis for tracking element exposure. Furthermore, a small 20 mg nail sample may be subjected to ICP-MS analysis (29).

ICP-MS applications to tissues

In addition to the typical matrices (blood and urine), hair and nails are important in clinical and forensic toxicology because they provide information on metal/metalloid exposure over a long period of time. Not to mention that hair and fingernails may be affected by outside pollutants. When blood and urine are absent from embalmed or decomposed cadavers, ICP-MS tissue analysis is actually the only technique available to identify a fatal outcome because of an element. In some cases, significant tissue concentrations are observed. Normal values for autopsy tissue and biopsy samples can be assessed using ICP-MS single or multi-elemental analysis. As with other biological matrices, the correctness of the results must be confirmed using certified material. In 2009, the 34elemental approach was described for evaluating normal tissue metal/metalloid concentrations in a range of tissues (brain, heart, kidney, liver, lung, and muscle) using 40 mg of tissue. Since the sample size may be reduced to 10 mg, biopsy samples can be subjected to multi elemental ICP-MS analysis (30). Table 1 shows a typical sample preparation for tissue, hair, nails, urine, plasma, or whole blood. To put it briefly, each sample uses a 0.3 ml volume of whole blood, plasma, or urine. Otherwise, pure nitric acid is used to digest 20 mg of tissue or 40 mg of nail or hair for an hour at 70°C. A portion of the digest solution is diluted in a dilution solution prior to analysis. Fingernails and toenails have certain advantages over hair because they contain more disulfide chemical groups, which enable them retain more metals and metalloids. Furthermore, nail development is less affected by traditional hair cosmetics and is more steady than hair growth. Additionally, compared to hair, toenails are less vulnerable to the damaging effects of external pollutants since they are protected by shoes. The section corresponding to a recent exposure is included in the matrix, which is a major disadvantage because it is not easily accessible. Because components are integrated into nails through the nail bed during thickening growth and by blood incorporation into the matrix during linear growth, their presence in nail clipping is linked to a prior exposure of three to five months. Finally, nail collection is noninvasive and provides an





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interesting alternative to hair, particularly when a person is bald or cannot be sampled due to religious beliefs. ICP-MS analysis may also be performed on a little 20 mg nail sample. Goullé JP et al. determined that 34 components in the fingernails and toenails of 50 healthy adults have a metallic character. The main results are shown in Table 2.

CONCLUSION

Mass Spectrometry is a very powerful technique in toxic substances identification, forensic analysis and in personalized medicine identification through pathology in clinical studies. MS tools like ICP-MS is used as advanced technique for identification of toxic metals in hair, nails and urine. ICP-MS is a sensitive technique where metals can be detected at very low concentration. This helps in patient monitoring and clinical diagnosis is made easy. In difficult situations including novel psychoactive drugs (NPS), undiscovered toxins, and therapeutic drug monitoring (TDM), MS-based toxicological techniques are very helpful. Additionally, by offering precise results with less sample preparation and quick turnaround times, MS improves the treatment of poisoning situations. Overall, mass spectrometry and its hyphenated applications are proving to be reliable, fast, and accurate analytical tools across various fields.

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Table 1. ICP-MS sample preparation³¹

	Whole blood	Plasma	Urine	Hair/Nail	Tissue
Sample	0.3ml	0.3ml	0.3ml	20mg	40mg
Nitric acid [pure]	No	No	No	0.2ml	0.2ml
Digestion	Freeze 1hr to hemolyze	No	No	70c 1hr	70c 1hr
Digestion sample	No	No	No	0.1ml	0.1ml
Nitric acid [2%]	No	0.1ml	No	0.1ml	0.1ml





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Standard addition	0.1ml	No	0.1ml	No	No
Dilution solution	2.6ml	2.6ml	2.6ml	3.8ml	3.8ml
<i>Dilution solution[v/v] nitric acid 1.0%, butanol 0.5%, triton 0.1%, for whole blood and 0.01% for plasma, nail and tissue, rodium and indium as internal standard[1µg/l]. Standards addition calibration for whole blood and urine, aqueous calibration for other matrices.</i>					

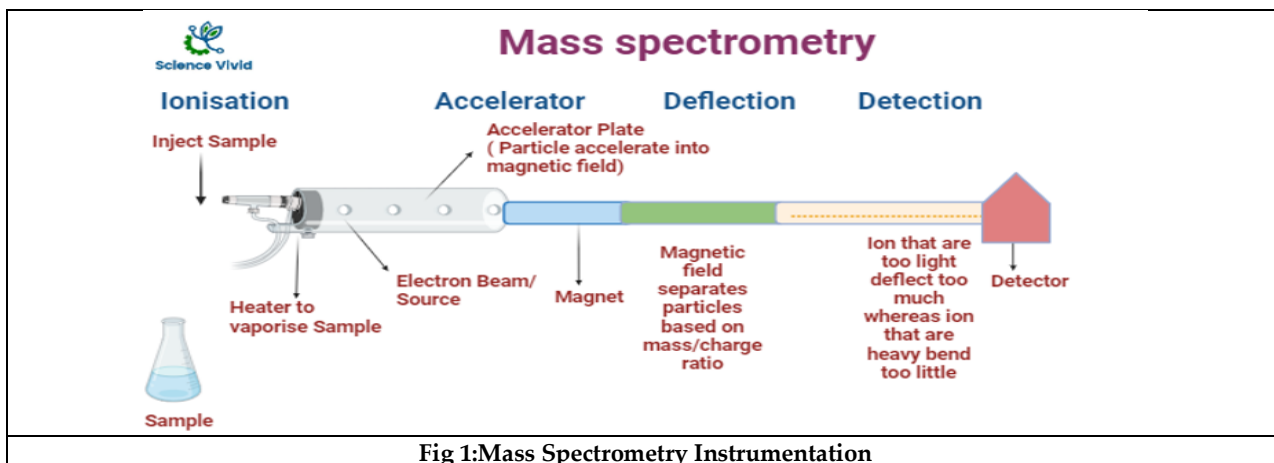
Table 2. Fingernail & Toenail values in Healthy volunteers³¹

S.NO	ISOTOPE OF METAL	Fingernail Median [µg/g]	Fingernail Reference range [5 th - 95 th percentile]	Toenail Median [µg/g]	Fingernail Reference range [5 th - 95 th percentile]
1.	Lithium	0.019	0.005-0.060	0.030	0.003-0.094
2.	Beryllium	0.005	0.001-0.010	0.005	0.001-0.010
3.	Boron	0.41	0.09-1.45	0.46	0.07-0.75
4.	Aluminium	14.9	4.9-36.6	10.7	2.3-30.9
5.	Vanadium	0.032	0.015-0.081	0.0279	0.007-0.070
6.	Chromium	0.42	0.18-0.76	1.14	0.11-8.75
7.	Manganese	0.36	0.14-1.67	0.36	0.12-2.08
8.	Cobalt	0.017	0.008-0.043	0.013	0.006-0.033
9.	Nickel	0.91	0.29-2.84	0.38	0.08-1.27
10.	Copper	6.5	4.3-9.4	3.6	2.1-6.8
11.	Zinc	108	83-143	83	63-105
12.	Gallium	0.032	0.015-0.120	0.029	0.012-0.102
13.	Germanium	0.004	0.003-0.010	0.003	0.002-0.008
14.	Arsenic	0.072	0.024-0.404	0.086	0.033-0.413
15.	Selenium	0.74	0.47-1.06	0.68	0.37-0.88
16.	Rubidium	0.17	0.05-0.45	0.48	0.24-1.21
17.	Strontium	0.031	0.28-1.00	0.94	0.32-2.08
18.	Molybdenum	0.35	0.006-0.034	0.007	0.003-0.010
19.	Palladium	0.028	0.011-0.072	0.040	0.011-0.067
20.	Silver	0.0003	0.04-1.55	0.028	0.009-0.137
21.	Cadmium	0.031	0.011-0.072	0.011	0.003-0.010
22.	Tin	0.35	0.16-0.68	0.10	0.03-0.35
23.	Antimony	0.028	0.014-0.086	0.026	0.009-0.083
24.	Tellurium	0.0003	0.0003-0.011	0.0003	0.0003-0.010
25.	Barium	0.65	0.26-2.44	0.56	0.20-1.98
26.	Lanthanum	0.033	0.004-0.17	0.022	0.003-0.11
27.	Gadolinium	0.002	0.0003-0.011	0.002	0.0001-0.007
28.	Tungsten	0.002	0.001-0.005	0.001	0.001-0.003
29.	Platinum	0.0002	0.0001-0.0005	0.0001	0.0001-0.0002
30.	Mercury	0.20	0.09-0.56	0.16	0.07-0.38
31.	Thallium	0.0003	0.0002-0.001	0.0005	0.0003-0.0009
32.	Lead	0.72	0.22-3.82	0.46	0.07-0.035
33.	Bismuth	0.011	0.003-0.130	0.004	0.001-0.035
34.	Uranium	0.003	0.001-0.005	0.002	0.001-0.006
<i>Dilution solution[v/v] nitric acid 1.0%, butanol 0.5%, triton 0.1%, for whole blood and 0.01% for plasma, nail and tissue, rodium and indium as internal standard[1µg/l] Standards addition calibration for whole blood and urine, aqueous calibration for other matrices.</i>					





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RESEARCH ARTICLE

Information in Multiple Facets and its Importance in Diverse Social Development

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ABSTRACT

In a progressively interconnected world, the complex character of information is essential for fostering social growth in various societies. This study examines the importance of knowledge as a dynamic resource that impacts multiple aspects of societal development, including economic growth, educational achievement, and social equality. Through the analysis of case studies from various areas, we demonstrate how access to diverse information formats, namely digital, visual, and experiential, empowers individuals and communities to make informed decisions, stimulates creativity, and improves civic involvement. Additionally, we examine the obstacles presented by information inequality and the digital divide, which may impede equitable growth. This study emphasizes the need to foster inclusive information ecosystems that address many needs and viewpoints, hence enhancing comprehensive social development and resilience in a swiftly evolving global environment.

Keywords: Additionally, we examine the obstacles presented by information inequality and the digital divide, which may impede equitable growth.





INTRODUCTION

Information is an abstract concept that possesses the capacity to inform. The English term "information" is derived from the Middle French words *enformation* or *information*. The term 'information' is etymologically linked to the Latin word 'information,' which denotes conception, instruction, and creation (**Sheldon, 2024b**). Information is an abstract concept that denotes a facet capable of fulfilling an individual's inquiry. At its core, the information relates to the interpretation of anything that can be actualized. In the contemporary digital age, information is more accessible, potent, and plentiful than ever before. The Internet has transformed the acquisition, sharing, and dissemination of information, facilitating immediate global connectedness and the democratization of knowledge (**Baudry & Monperrus, 2015**). Currently, online platforms, search engines, and social media serve as primary sources of information for persons worldwide for effective utilization. The purpose of the study "Information in Multiple Facets and its Importance in Diverse Social Development" is probably to investigate the different aspects of information and how important it is for fostering empathy, creativity, and social cohesiveness in a variety of social contexts.

REVIEW OF RELATED LITERATURE

In the digital age, the idea of information has changed dramatically, impacting many aspects of social growth. Gaining knowledge about the ways in which information functions in various contexts can help one better understand how it promotes empathy, creativity, and social cohesiveness in a variety of cultures. **Shannon and Weaver (1949)** established the foundation for comprehending information as a quantifiable thing. They underscored the significance of clarity, precision, and pertinence in communication, which are essential for effective social advancement. **Vygotsky (1978)** asserts that social interactions and cultural settings influence the process of knowledge acquisition. This approach emphasizes the significance of many information sources in promoting community engagement and growth. Studies demonstrate that access to varied information fosters social cohesion by facilitating understanding and diminishing prejudices (**Putnam, 2000**). Communities with abundant informational resources are more adept at fostering constructive debate, resulting in enhanced social cohesion. Empathy is essential for social growth, and information can facilitate empathic reactions. Research by **Batson et al. (1997)** indicates that exposure to many narratives can improve sympathetic comprehension, therefore fostering social cohesion. The correlation between information and innovation is extensively recorded. **Nonaka and Takeuchi (1995)** contend that knowledge development is a social process that flourishes on varied information inputs. This is especially pertinent in multicultural environments where diverse viewpoints can result in unique solutions.

Comparative research elucidates the distinct methods by which other cultures employ information to promote social development. **Hofstede's (1980)** cultural aspects theory exemplifies the impact of cultural values on information processing and distribution. According to Collins English Dictionary, information is "1. an informing or being informed; esp., a telling or being told of something 2. something told; news; intelligence; word 3. knowledge acquired in any manner; facts; data; learning; lore 4. a person or agency answering questions as a service to others 5. in information theory and computer science, a precise measure of the information content of a message, measured in bits and ranging from zero when the entire message is known in advance to some maximum when nothing is known of its content 6. any data that can be stored in and retrieved from a computer". According to OED: Oxford English Dictionary, the historical English Dictionary, information is: "Knowledge communicated concerning some particular fact, subject, or event; that of which one is apprised or told; intelligence, news". According to Wikipedia, "Information is an abstract concept that refers to that which has the power to inform. At the most fundamental level, the information pertains to the interpretation (perhaps formally) of that which may be sensed or their abstractions". According to the Online Dictionary for Library and Information Science (ODLIS), Information is: "Data presented in a readily comprehensible form to which meaning has been attributed within the context of its use. In a more dynamic sense, the message is conveyed by the use of a medium of communication or expression. Whether a specific message is informative or not depends in part on the subjective perception of the person receiving it". "More concretely, all



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the facts, conclusions, ideas, and creative works of the human intellect and imagination that have been communicated, formally or informally, in any form”.

Objective of the Study

The research's core objectives can be classified into three essential domains. Each purpose seeks to investigate various aspects of how knowledge impacts social development throughout different cultures.

- To give a thorough explanation of the idea of information in all of its aspects and the role it plays in various stages of societal growth.
- To recognize the different aspects of knowledge and how they contribute to the development of empathy, creativity, and social cohesiveness.
- to investigate the ways in which various types of information can be used to improve empathy and social cohesiveness in communities.
- To predict possible results of employing knowledge across several domains to improve social cohesiveness and foster innovation in different contexts.

Data, Information, Knowledge, and Wisdom

Data must constantly be processed to render it meaningful. Consequently, data transforms into information, knowledge, and wisdom in succession. The Data-Information-Knowledge-Wisdom (DIKW) framework illustrates the progression from raw data to significant insights through successive phrases (Cotton, 2023).

- D for Data;
- I for Information;
- K for Knowledge; and
- W for Wisdom.

DIKW represents a sequential process characterized by a hierarchical paradigm, sometimes illustrated as a pyramidal structure with facts at the base and wisdom at the pinnacle.

Types of Information

Typically, there are four categories of information: Factual, Analytical, Subjective, and Objective.

Factual information

Information that is factual is linked to facts. Almanacs, manuals, handbooks, encyclopedias, and other reference books are the best source of factual knowledge. Interviews, recipes, instructions, news stories, conversions between various measurements, national and international events, historical documents, and more are examples of factual information.

Analytical information

By offering a higher degree of insight and interpretation, analytical information aids in our comprehension of the correct meaning and significance of factual information. Bar charts, pie charts, statistical analyses, tabular data presentation, statistical mathematics, graphical measures, and more are examples of analytical information.

Subjective information

Numerous sources, such as books, journals, websites, and book reviews, contain subjective information. This kind of information is distinguished by its dependence on accepted facts as well as by the inclusion of subjective viewpoints, unique experiences, and emotional states, all of which add to its intrinsically diverse and personal character. Such data, as opposed to just objective data, offers a more personalized and detailed perspective. Textual information, facts presented in significant main sources of information, experiences communicated, etc.



**Rama Pal and Mohammad Nasir****Objective information**

Facts on file, common reference books, directories, etc. are examples of sources of objective information. Objective information is documented to provide a thorough grasp of a topic. Information for instant reference, verified facts, evidence-based details, and other similar kinds are examples of objective information.

Types of Information Sources

To make it readily usable, information is produced in a variety of methods and recorded in a number of sources. We obtain our information from a variety of sources, including records, people, organizations, and the media. Every one of these information sources is essential for supplying insightful data. These resources are essential for both individuals and organizations because they foster well-informed decision-making, improve comprehension, and provide a comprehensive viewpoint on a range of topics.

Documentary Sources of Information

Information from documentary sources includes a wide variety of recorded recordings, regardless of their format or topic. These documentary sources are systematically divided into the following categories, according to library and information science experts:

Documentary sources, according to Dr. S. R. Ranganathan

Documentary sources of information fall into four different types, according to library science pioneer Dr. S. R. Ranganathan. These classifications, which show how information formats have changed over time and are based on their physical characteristics, consist of:

Conventional: Such as books, periodicals, maps, and atlases.

Non-Conventional: Including standards, specifications, patents, and data.

Neo-Conventional: Comprising audio recordings, visual materials, audio-visual content, and microforms.

Meta Documents: Encompassing documents created directly through technological means without human intervention.

Documentary Sources, According to W. Hanson

In an article titled "Introduction to Science Information Work," published in 1971 by ASLIB, W. Hanson, the former editor of the *Journal of Documentation*, categorized documentary sources of information into three distinct groups:

- **Primary Sources of Information**
- **Secondary Sources of Information**

Documentary Sources, According to Denis Joseph Grogan

D. J. Grogan, a renowned British information scientist and educator, categorized documentary information sources into three distinct groups:

- **Primary Sources**
- **Secondary Sources**
- **Tertiary Sources**

Primary- sources of information, according to Grogan

According to Grogan, primary sources of information are those in which the author presents original evidence, describes a new discovery, proposes a novel idea, or introduces new evidence related to previous claims. These primary sources include:

- Primary periodicals
- Patents
- Standards
- Research reports
- Dissertations and theses



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- Reprints
- Trade literature
- Influential books
- Personal documents such as letters, diaries, and papers
- Photographs
- Interviews and transcripts
- Government and historical records
- Newspaper articles and clippings

Secondary Sources of Information, According to Grogan

Grogan claims that secondary sources of knowledge are distinguished by their concentration on a particular topic via the examination and interpretation of primary sources. To produce a more readable format, these papers entail the selection, alteration, organization, and repackaging of original data (Admin, 2021). By offering summaries, reviews, or compilations based on the fundamental research contained in primary sources, secondary sources aim to make the material easier for the end user to find and use.

Tertiary- Sources of Information According to Grogan

Grogan defines tertiary sources of information as those that appear later in the research process and typically don't provide in-depth subject matter. These resources serve as tools to assist users in finding and accessing primary and secondary sources, with the primary goal of informing users about additional sources. Helping users locate and make efficient use of primary and secondary materials is the major function of tertiary sources (Teaching & Learning, University Libraries, n.d.). Bibliographies of bibliographies, yearbooks, directories, literature guides, organizational guides, and lists of active research are a few examples of tertiary sources.

Non-Documentary Sources of Information

Non-documentary sources of information are those which are not recorded in any form. The sources under this category are:

- i) Humans;
- ii) Organizations;
- iii) Mass media (other than print and cyber media); and
- iv) Cyber media.

Humans

Humans provide valuable information that has not been documented in any manner. Individuals, from specialists to ordinary citizens, serve as significant sources of information based on the type and quantity of information needed (Studocu, 2022.). The perspective of an expert is invariably significant. When a researcher faces an issue during their investigation and needs an immediate solution, consulting an expert can be quite beneficial.

Organizations

Organizations serve as significant sources of information. Organizations such as libraries, information centers, archives, academic institutions, research and development institutions, museums, publishing houses, and government agencies deliver accurate, reliable, and timely information within their respective domains (H. J. Singh, 2022). This type of information is not available elsewhere.

Mass media (other than print and cyber media)

The channels via which news, information, and broadcasts are effectively disseminated to the general public are referred to as mass media. Mass media, excluding print and digital platforms, such as television and radio, plays a significant role in the dissemination of effective information and is regarded as the most viable medium in contemporary society. The majority of individuals engage with and interact with these media.



**Rama Pal and Mohammad Nasir****Cybermedia**

In the modern digital environment, cybermedia is a crucial and essential source of information. Media related to online communication or cyberspace are termed cyber media. Interactive digital platforms, such as the Internet, differ from traditional channels like printed materials and television. Cyberspace is the electronic environment of computer networks where online information transmission occurs.

Value of Information in Society

The significance of information in society, particularly regarding library and information services, is substantial. These serve a crucial function in safeguarding and providing access to information, acting as reservoirs of knowledge and intellectual resources (Chatterjee, 2016). Several major characteristics that underscore the significance of information in society include the following.:

Access to knowledge

Libraries and information centers function as portals to extensive realms of information and knowledge. They curate a collection of books, journals, databases, and several other materials that encompass a broad spectrum of disciplines. By granting access to information, they enable individuals to acquire knowledge, investigate novel concepts, refine their abilities, and make educated judgments.

Empowering individuals

Access to knowledge is crucial for individual development, education, and empowerment. Consequently, libraries and information centres are vital for lifelong learning by providing comprehensive resources and services to individuals of all ages, economic statuses, and cultural or religious backgrounds. By fostering an inclusive environment, they enhance personal development throughout their life.

Bridging the digital divide

Libraries frequently offer public access to computers, digital materials, and the Internet. This addresses the digital divide, ensuring that persons without personal access to technology can nevertheless access online information and services. Libraries are essential in fostering digital literacy and ensuring equitable access for all members of society.

Promoting research and innovation

Libraries and information centres are essential institutions for academics, students, educators, and professionals across diverse disciplines. They grant access to academic journals, research databases, and additional resources, thereby promoting research and innovation. Libraries provide professional assistance, reference services, and interlibrary lending networks, linking customers to materials outside their local holdings.

Preserving cultural heritage

Libraries function as guardians of our cultural heritage, safeguarding books, manuscripts, archives, pictures, and other significant materials. Through the collection, archiving, and preservation of these resources, libraries guarantee that future generations will have access to historical records, literature, and cultural artifacts.

Community engagement

Libraries serve as community centres, fostering civic participation, social interaction, and cultural exchange. They provide a range of activities and events, including exhibitions, seminars, lectures, and book clubs, which cultivate a feeling of community and create opportunities for individuals to meet, learn, and exchange ideas.

Information Literacy

Libraries are essential in promoting information literacy by instructing users on how to discover, critically evaluate, and efficiently utilize information in many contexts. In the contemporary day, characterized by an overwhelming influx of information and widespread disinformation, libraries function as vital resources in assisting individuals to



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cultivate robust critical thinking abilities. They enable users to identify reliable sources, navigate intricate information environments, and make educated choices, thus contributing significantly to the development of an informed and reflective society. The significance of information in society, as advocated by libraries and information centers, is paramount. They contribute to research, the teaching-learning process, holistic human development, political cognition in a democracy, cultural preservation for future generations, and community development. They consistently promote the cultivation of an informed and knowledgeable society, empowering individuals to make informed decisions that contribute to their communities and society at large.

Barriers to Information Communication in Society

The primary obstacles in information communication include inadequate information handling skills, insufficient resources, time constraints, competing work pressures, lack of confidence, and absence of motivation and incentives, among other challenges. Obstacles to information communication can stem from multiple causes that impede the seamless exchange of information between persons or organizations (McLaughlin & McLaughlin, 1989). Several prevalent hurdles may be identified as follows:

Language barriers

Differences in language can affect effective communication, especially when individuals involved do not understand each other's languages. This barrier can be overcome through translation services or by the use of common languages.

Technological barriers

Restricted access to technological resources or reliance on obsolete infrastructure might impede information dissemination. Moreover, limited Internet access, sluggish Internet speeds resulting from inadequate capacity, absence of essential devices, and incompatible systems might hinder the flow of information.

Cultural and social barriers

Cultural disparities in norms, values, and social customs might influence communication. Misinterpretation of gestures, conventions, or traditions can result in misunderstandings or disputes. It is essential to acknowledge cultural sensitivity for the effective acceptance of communication methods.

Physical distance

Geographical distance is a problem for communication, particularly when persons or organizations are situated at considerable separations. Physical barriers, like time zones, extensive distances, and remote regions with inadequate infrastructure, impede timely and effective information sharing among users.

Lack of Information literacy

A lack of proficiency in accessing, assessing, and utilizing information might hinder successful communication. Many consumers are unfamiliar with navigating digital platforms for accessing online information and are not accustomed to utilizing the proper communication tools.

Information overload

In the contemporary digital era, the overwhelming amount of information might be challenging. There is an observable information explosion, occasionally resulting in duplications of the generated data. Information overload can impede efficient communication, since individuals may struggle to sift, analyse, and prioritise the available information.

Organizational barriers

Hierarchical structures, bureaucracy, and inadequate internal communication within organisations can obstruct the flow of information. Insufficient transparency, inefficient information dissemination procedures, or an inappropriate culture that may inhibit open communication.



**Rama Pal and Mohammad Nasir****Psychological barriers**

Personal characteristics such as bias, prejudice, and individual attitudes can impede successful communication. Preconceived conceptions, reluctance, resistance to change, or emotional turmoil might impede the open exchange of information. There are occasionally legitimate obligations to maintain confidentiality.

Digital divide

Another significant hurdle is the existence of a digital divide in society, resulting in unequal access to digital technologies, such as smartphones, tablets, laptops, and the Internet.

Regulatory barriers

Legislation and laws concerning data protection, privacy, patents, copyrights, and various forms of intellectual property rights (IPR) may impede information exchange. Consequently, adherence to rules and limitations regarding the transfer of specific information kinds can affect the unrestricted exchange of communication.

CONCLUSION

Information is an essential component of library and information science. Furthermore, library and information science is an essential field for facilitating access to, protecting, and efficiently managing information resources. Information denotes knowledge that has been systematically organized and processed, rendering it available via several mediums including books, journals, databases, and the Internet. This domain encompasses the procurement, categorization, preservation, and dissemination of information to suit the requirements of various users. Advancements in information technology (IT) have expanded the reach and accessibility of information through digital resources such as electronic journals, online databases, and e-books. Information is essential in our daily lives, with its need spanning all areas and specialties. Access to pertinent and precise information is crucial for personal growth as well as cultural, economic, educational, and scientific advancement, facilitating informed decision-making and the attainment of our enlightened objectives. Consequently, the demand for knowledge has intensified in the contemporary, rapidly evolving environment. Individuals and organizations require access to current research, trend analyses, and innovative concepts to maintain competitiveness and relevance. Visionaries and futurologists assert that we are entering an era predominantly characterized by the interchange of knowledge in trade.

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